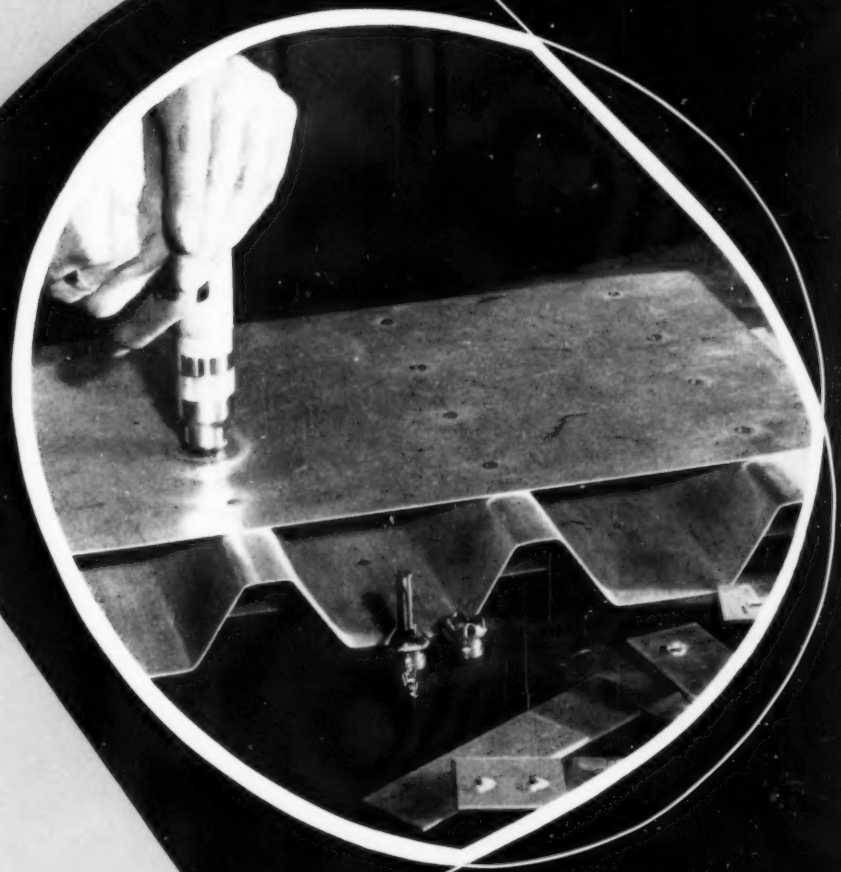
BRITISH WELDING JOURNAL

1960 DECEMBER

VOL. 7 NO. 12



CONTENTS

The Problem of Welding High-Temperature Service Materials
By E. Kauhausen, P. Kaesmacher, and S. Sadowski

Hot Pressure Welding of Titanium
By C. F. Wilford and R. F. Tylecote

Cover Illustration
see p. 718

A *Unique* Process for Economy in HEAVY WELDING

'VERTOMATIC'

VERTICAL WELDER

Have you seen the 'Vertomatic' in operation? Have you considered its economic advantages relative to your particular business? The electroslag process and the 'Vertomatic' have features which set them apart from other forms of electro-welding. A sound method of evaluation is a comparison with submerged arc welding.

Here are the facts:—

1. *No elaborate and costly edge preparation. 'Vertomatic' requires only a plain firm edge irrespective of sectional thickness.*
2. *'Vertomatic' requires only ONE SETTING for any joint and there is no limit to plate thickness.*
3. *No slag removal or surplus flux recovery problem.*
4. *Complete homogeneous heat distribution throughout weld depth eliminates distortion difficulties.*
5. *Substantial manpower and materials savings.*

Obviously it will pay you to witness a practical demonstration of this machine—telephone or write us and we will arrange it to suit your convenience. Why not now—while you have the 'Vertomatic' in mind?

ROCKWELD LTD

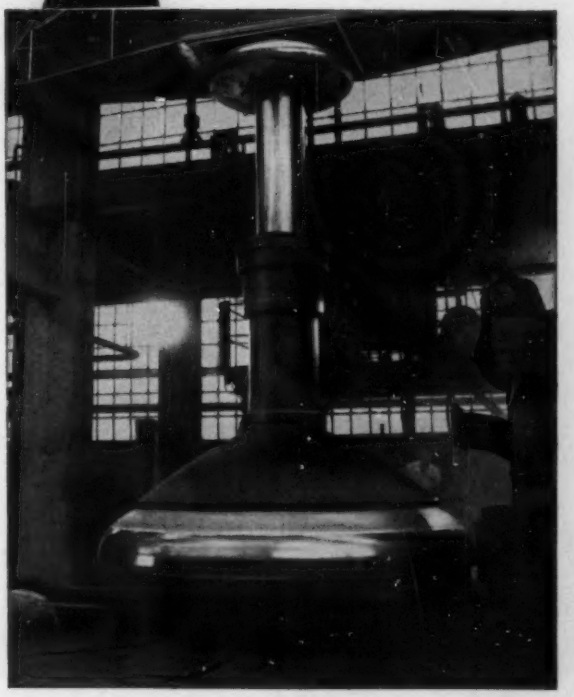
Commerce Way · Croydon · Surrey

Tel: Croydon 7161

Over a Ton

of Aluminium Alloy spun to 10 ft. i/d x $1\frac{5}{8}$"

One of a number produced for pressure vessels to hold liquid air, this 10 ft. aluminium end was spun by Harveys on the Rotarpress. The 12 ft. flat discs needed for spinning these ends, which are believed to be the largest spun aluminium ends produced in this country, were formed by butt-welding two plates of aluminium alloy together.



The Rotarpress is one of the large-capacity units in Harveys Heavy Fabrication Department. It produces ends up to 15 ft. diameter and is adaptable over a wide range of knuckle radii and depths.

The contours of semi-ellipsoidal ends produced by the spinning process enable plate thickness to be reduced, and in most cases tool costs are eliminated. Enquiries are invited for ends only or for complete

FABRICATION OF PRESSURE VESSELS.

HARVEY

G. A. HARVEY & CO. (LONDON) LTD.

Woolwich Road, London, S.E.7. GREenwich 3232 (22 lines)

Other Harvey facilities: FABRICATIONS UP TO 120 TONS IN ONE PIECE · HEAVY MACHINING AND FITTING · HEAT TREATMENT AND RADIOGRAPHY · STEEL PLATE AND SHEET METALWORK · PERFORATED METALS · WOVEN WIRE · WIREWORK H9/7

ROBEY
OF LINCOLN

introduces you to first-class work,
punctual, early delivery
and very competitive prices

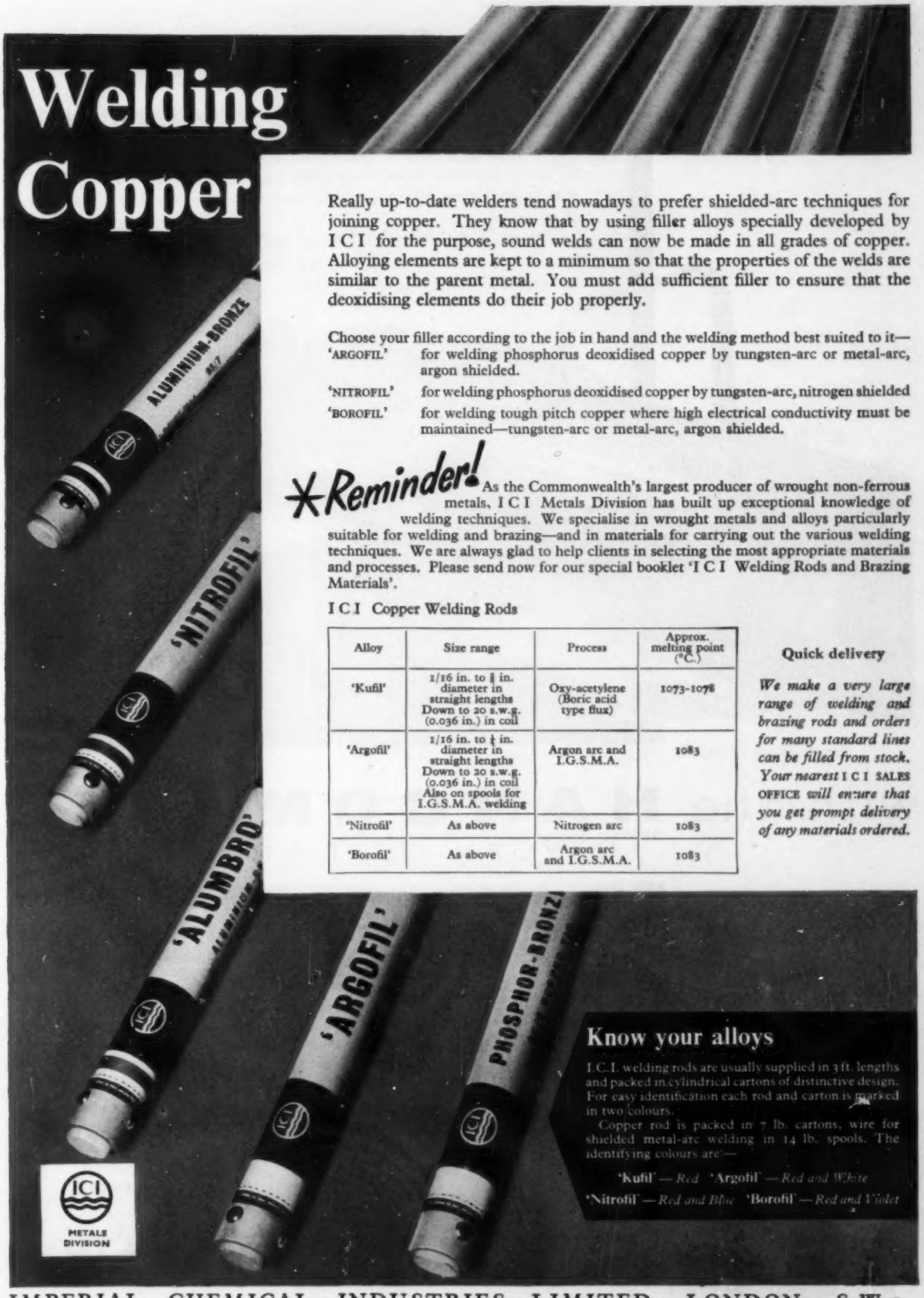
Regular production includes Lloyds Class 1 Pressure Vessels.

Special assignments include trunnions for the Jodrell Bank telescope; pressure vessels and special machines for nuclear power.

For WELDING

Robey & Co. Ltd. · P.O. Box 23 · Lincoln
London Office: 11 Princes St., Hanover Sq., W.1

Welding Copper



Really up-to-date welders tend nowadays to prefer shielded-arc techniques for joining copper. They know that by using filler alloys specially developed by I C I for the purpose, sound welds can now be made in all grades of copper. Alloying elements are kept to a minimum so that the properties of the welds are similar to the parent metal. You must add sufficient filler to ensure that the deoxidising elements do their job properly.

Choose your filler according to the job in hand and the welding method best suited to it—

'ARGOFIL' for welding phosphorus deoxidised copper by tungsten-arc or metal-arc, argon shielded.

'NITROFIL' for welding phosphorus deoxidised copper by tungsten-arc, nitrogen shielded

'BOROFIL' for welding tough pitch copper where high electrical conductivity must be maintained—tungsten-arc or metal-arc, argon shielded.

*Reminder! As the Commonwealth's largest producer of wrought non-ferrous metals, I C I Metals Division has built up exceptional knowledge of welding techniques. We specialise in wrought metals and alloys particularly suitable for welding and brazing—and in materials for carrying out the various welding techniques. We are always glad to help clients in selecting the most appropriate materials and processes. Please send now for our special booklet 'I C I Welding Rods and Brazing Materials'.

I C I Copper Welding Rods

Alloy	Size range	Process	Approx. melting point (°C.)
'Kufil'	1/16 in. to ¼ in. diameter in straight lengths Down to 20 s.w.g. (0.036 in.) in coil	Oxy-acetylene (Boric acid type flux)	1073-1078
'Argofil'	1/16 in. to ¼ in. diameter in straight lengths Down to 20 s.w.g. (0.036 in.) in coil Also on spools for I.G.S.M.A. welding	Argon arc and I.G.S.M.A.	1083
'Nitrofil'	As above	Nitrogen arc	1083
'Borofil'	As above	Argon arc and I.G.S.M.A.	1083

Quick delivery

We make a very large range of welding and brazing rods and orders for many standard lines can be filled from stock. Your nearest I C I SALES OFFICE *will ensure that you get prompt delivery of any materials ordered.*

Know your alloys

I.C.I. welding rods are usually supplied in 3 ft. lengths and packed in cylindrical cartons of distinctive design. For easy identification each rod and carton is marked in two colours.

Copper rod is packed in 7 lb. cartons, wire for shielded metal-arc welding in 14 lb. spools. The identifying colours are:—

'Kufil' — *Red* 'Argofil' — *Red and White*

'Nitrofil' — *Red and Blue* 'Borofil' — *Red and Violet*

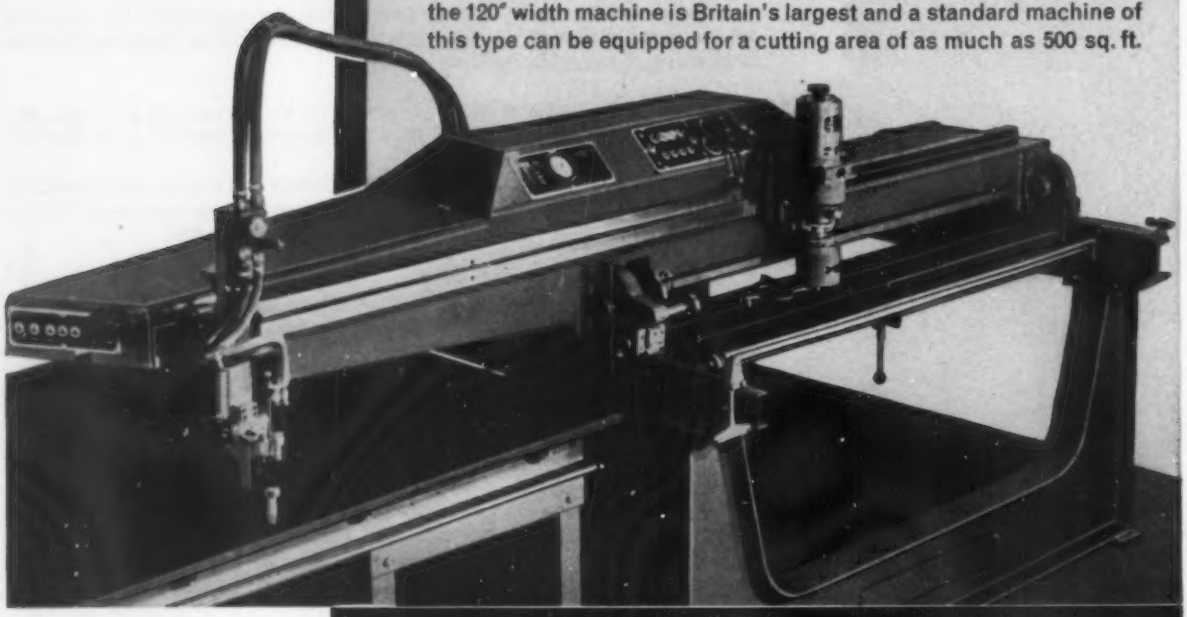
ICI METALS DIVISION

IMPERIAL CHEMICAL INDUSTRIES LIMITED, LONDON, S.W.1.

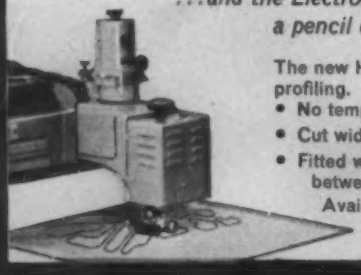
Cut a fine figure...

The new Hancomatic embodies the best principles of oxygen cutting in a handsome, streamlined machine. With the Hancomatic it's top speed precision cutting every time and saving in time and labour all along the line. New electrically operated oxygen cutting valve with instant shut-off, new tracer head for operation from templates of all types.

The Hancomatic is available in 40″, 62″, 90″ and 120″ cutting widths; the 120″ width machine is Britain's largest and a standard machine of this type can be equipped for a cutting area of as much as 500 sq. ft.



with the HANCOMATIC
OXYGEN CUTTING MACHINE



...and the Electronic **HANCOLINE** *which traces from a pencil drawing automatically.*

The new Hancoline brings absolute simplicity to oxygen profiling.

- No templates needed—no storage problems.
- Cut width compensation on tracer head.
- Fitted with Hancock roller drive—no physical contact between tracer and drawing.

Available with 38″, 60″, 90″ and 120″ cutting widths.

1st The first name in OXYGEN CUTTING HANCOCK HANCOCK CUTTING MACHINES

Write for details

HANCOCK & CO. (Engineers) LTD.

Progress Way, Croydon, Surrey · Telephone: Croydon 1908 · Cables: Hanco Croydon.

When the 'right time' is essential

in process cycles

or welding current duration

depend on AEI electronic timers

GENERAL PURPOSE AND PROCESS WORK—TYPE FU21

- Available from stock in timing ranges covering 0·5 to 180 seconds
- No moving parts in timing circuit
- Easily arranged to operate in individual control schemes
- High repetitive accuracy
- Suitable for 40/60 cycle a.c. supplies of 110, 200/250, or 400/440 volts

WELDING—TYPE FW19

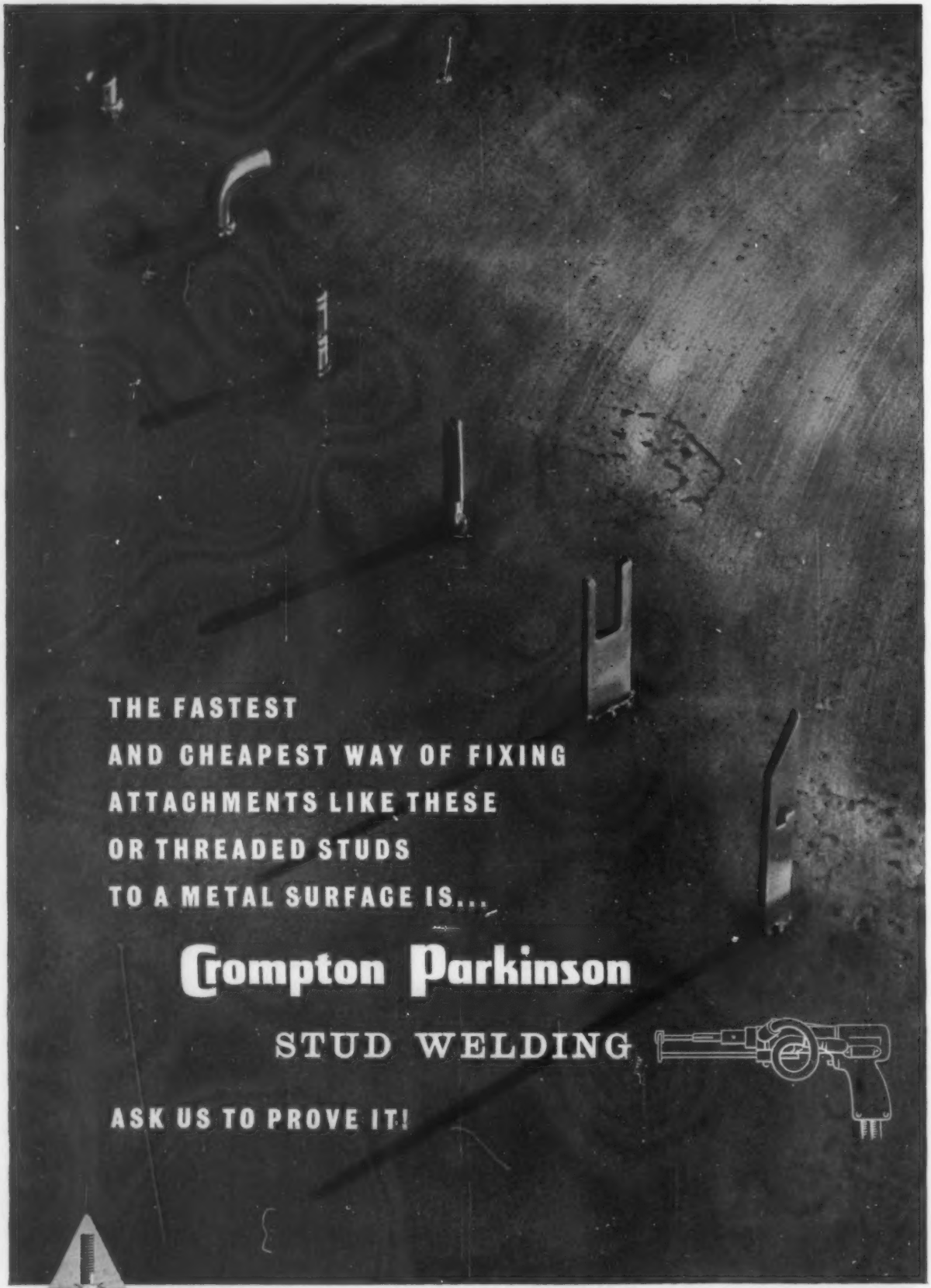
- For control of resistance welding machines
- Timing range 0·1 to 10 seconds
- No moving parts
- Supplied with separate rheostat for remote setting
- Available from stock for immediate delivery

Please write for further technical details.
Our engineers will be pleased to help you with your automatic timing problems.

AEI

Associated Electrical Industries Limited
Electronic Apparatus Division
NEWPARKS, LEICESTER, ENGLAND

A5385


THE FASTEST
AND CHEAPEST WAY OF FIXING
ATTACHMENTS LIKE THESE
OR THREADED STUDS
TO A METAL SURFACE IS...
Crompton Parkinson
STUD WELDING
ASK US TO PROVE IT!
Cramp-Arc
CROMPTON PARKINSON (STUD WELDING) LTD · 1-3 BRIXTON ROAD · LONDON SW9 · TEL: RELIANCE 7676

A CO_2 cylinder of new construction is now available. When full with 50 lbs. of liquid CO_2 it will weigh little more than the present full 28 lb. cylinder—much easier for handling and storage. The cylinder is fitted with a plastic syphon tube and used in conjunction with the heater, ensures constant moisture content throughout withdrawal. (In a conventional cylinder considerable variation in moisture content is inevitable).
The new 50 lb. cylinder will be specially painted, labelled and handled to avoid confusion with other types.

CO_2 for Arc Welding

new cylinder—specially designed for arc welding

DCL

Carbon Dioxide

SUPPLY
Bulk Liquid and Cylinders

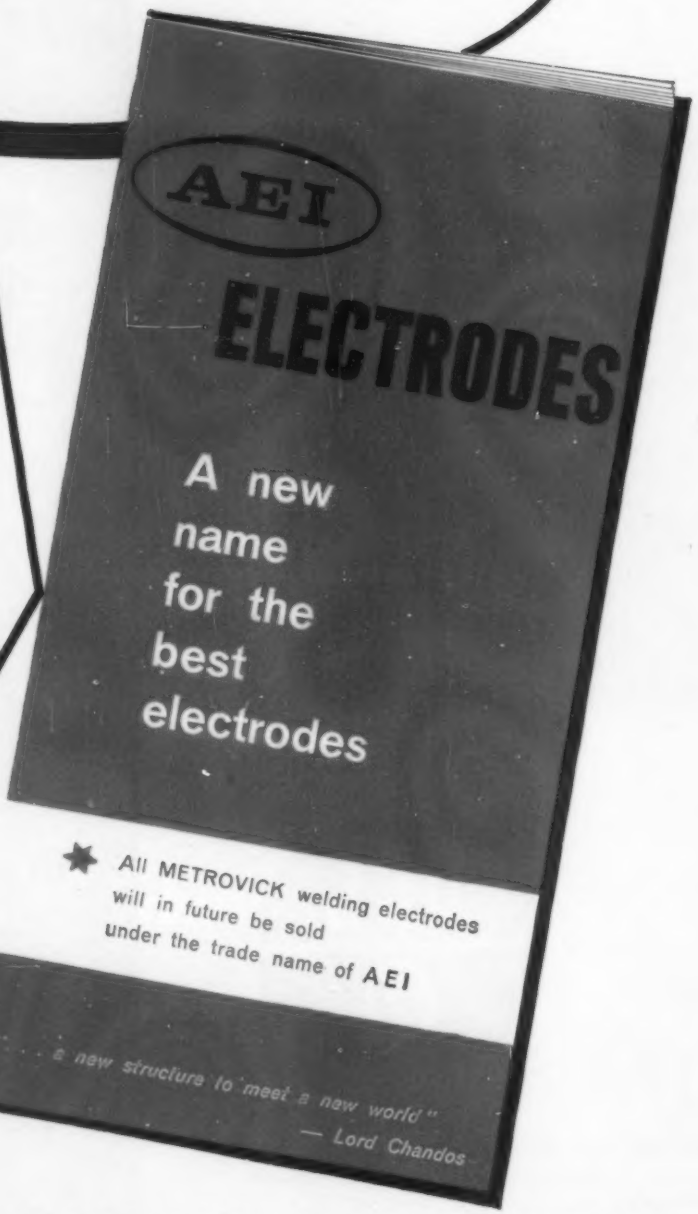
STORAGE
Installation and Maintenance

THE DISTILLERS COMPANY LIMITED · CHEMICAL DIVISION
Carbon Dioxide Department · Devonshire House
Piccadilly · London W1 · MAYfair 8867

Sales Offices:
Southern Area: Broadway House, The Broadway, Wimbledon SW19. Liberty 4661
Northern Area: Queens House, Queen Street, Manchester 2. Deansgate 8877

TA4131

Electrodes worthy of the welder


AEI
ELECTRODES
A new name for the best electrodes
All METROVICK welding electrodes will in future be sold under the trade name of AEI
"a new structure to meet a new world"
— Lord Chandos

SEND FOR YOUR COPY TODAY

This new edition of the Pocket Electrode Guide provides full technical information on the complete range of AEI electrodes. There are over 50 pages of useful facts and figures. May we send you a copy?

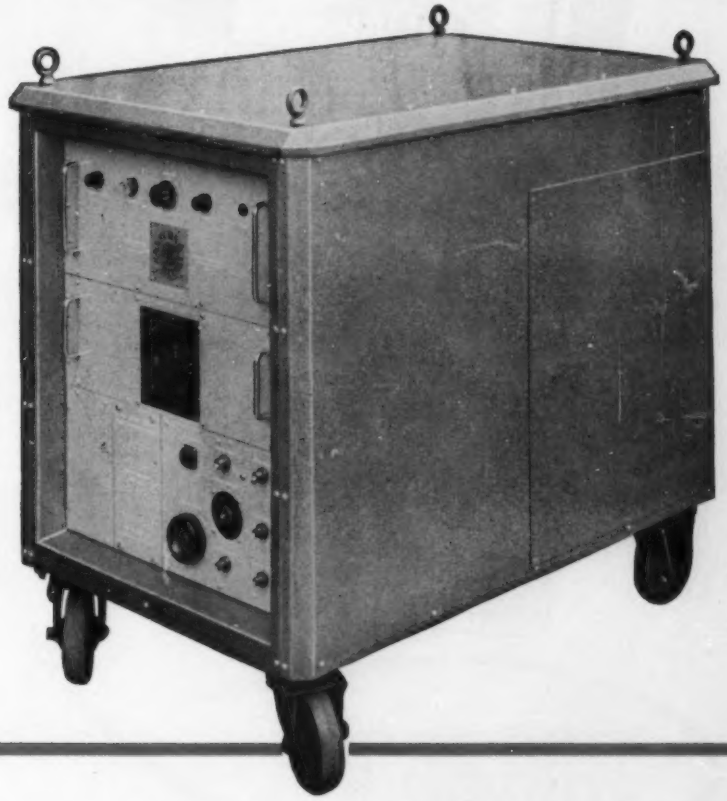
AEI **Associated Electrical Industries Ltd.**

Transformer Division **Heating & Welding Department**

TRAFFORD PARK, MANCHESTER 17.

L/P902

the SATURN-HIVOLT



Surge Injector Argon Arc Welding Units Mk. II and III

permits welding from 30 to 600 amps

The Saturn Hivolt Argon Arc Welding machines, Mk.II and Mk.III, operating on the surge injector principle, offer industry many advantages in safety, performance and ease of operation. Both models are completely self-contained having built-in transformers of 42v open circuit AC supply and fully automatic control circuits for water, gas and welding current.

Welding ranges are infinitely variable between 30—300 amps (Mk.II) and 60—600 amps (Mk.III): either machine can be adapted to meet customers special requirements.

A demonstration of these machines will gladly be given in your own factory.

SATURN INDUSTRIAL GASES LIMITED

'Erl Wood' Windlesham, Surrey. Telephone: Bagshot 2441

BRANCHES: LONDON · GLASGOW · ALDRIDGE · BIRMINGHAM · MANCHESTER
SHEFFIELD · LYMINGTON · SUNDERLAND · THORNABY-ON-TEES

THIS BOOK CAN SAVE MORE IN YOUR PLANT

Eutectic have specialised in advanced metal-joining techniques for more than 50 years, and today the unique "Low Heat Input" process enables you to REPAIR WELD – SAVE MORE on your equipment. Warping, distortion and embrittlement are minimised and long lasting repairs are made stronger, faster and more safely with EUTECTIC.

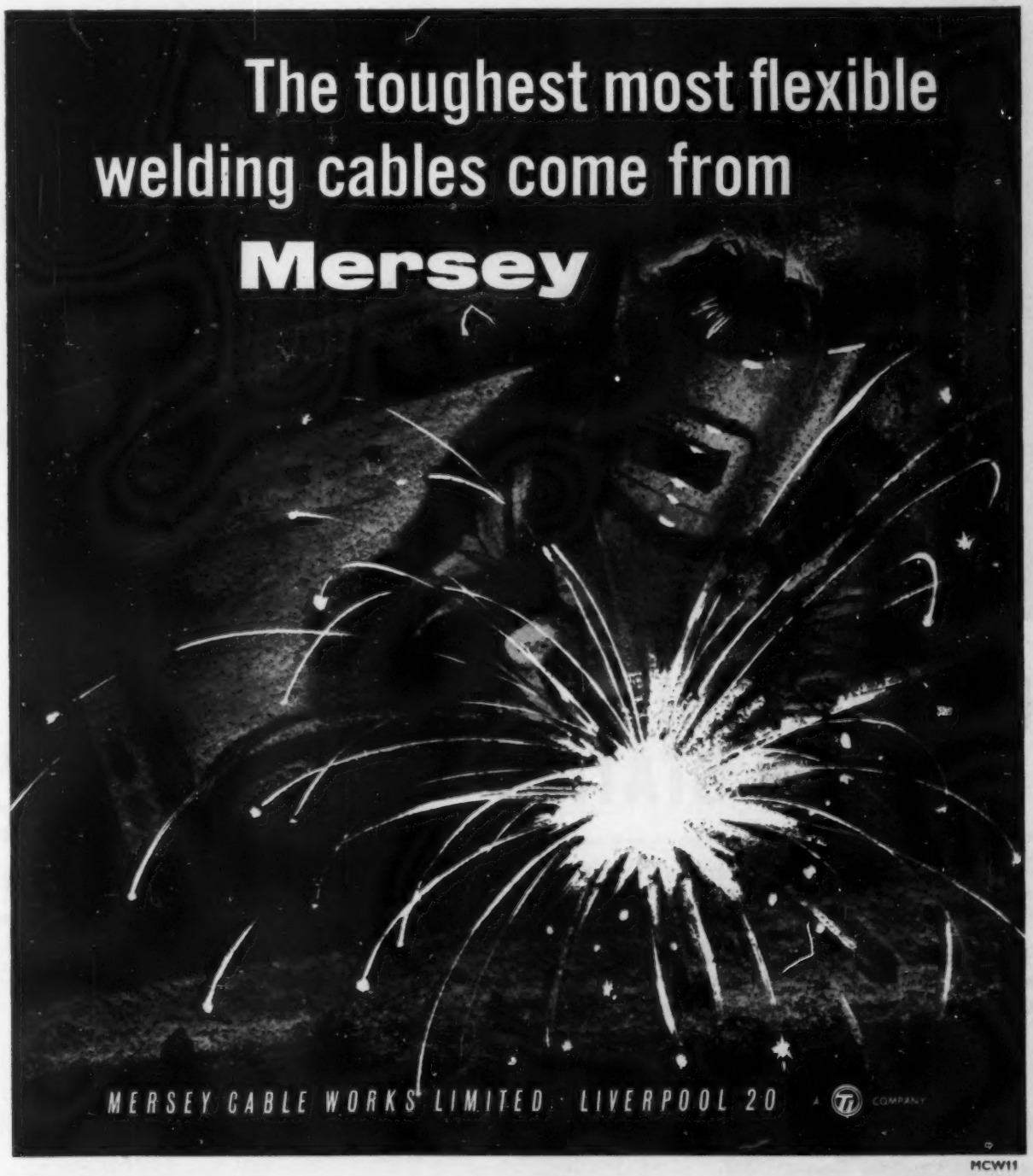
Read in the new Maintenance Welding Data Book how you can save with on-the-spot repairs avoiding costly downtime, and wear-resistant overlays which considerably lengthen working life. This fact-crammed 68 page book is available free of charge from your local Eutectic technical representative. Other services to industry include free technical advice, demonstration, and training schemes. To get your copy fill in the coupon today.

The world's leading metal-joining institution with plants in London, New York, Lausanne, Frankfurt, Paris, Montreal, Johannesburg, Bombay, Melbourne, Tokio, Mexico City, Puerto Rico and Sao Paulo. Research Centres in U.S.A. and Switzerland. Affiliated companies in Brussels, Vienna, Caracas, Lima and Buenos Aires. Sales and service throughout the world.

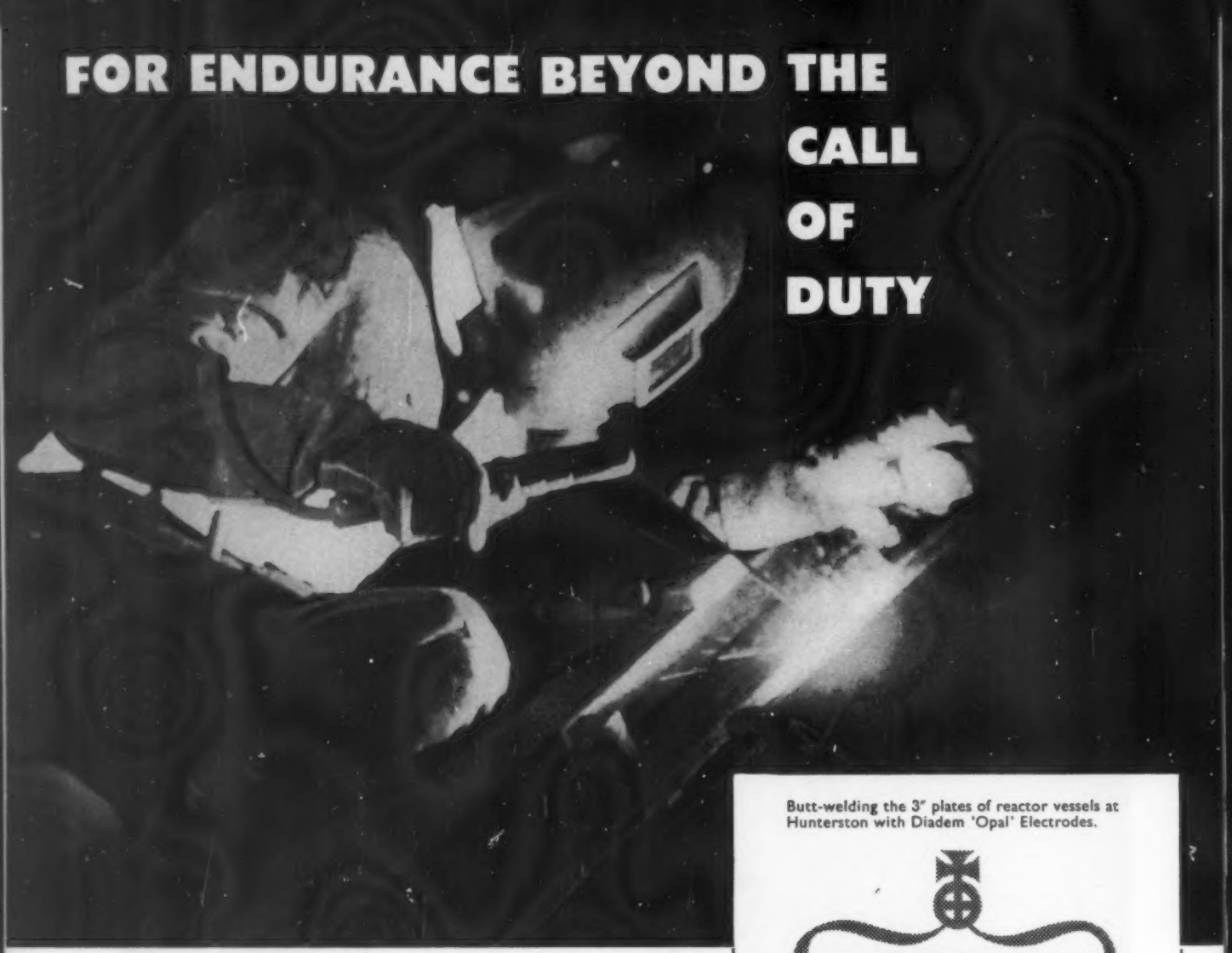
EUTECTIC WELDING ALLOYS COMPANY LTD
NORTH FELTHAM TRADING ESTATE, FELTHAM, MIDDLESEX. Phone: FEL 6571

EUTECTIC–PLEASE SEND
☐ Free Data Book
☐ Weld Saving Report
NAME _____
BUSINESS ADDRESS _____
_____
_____ B.W.J.23

Dragged and scuffed through half the world's shipyards, construction sites and engineering works, Mersey Welding Cables show remarkable indifference to their hard life—being just as likely to go on serving you long after others have outlived their usefulness. In part, this extraordinary toughness and flexibility is due to the care and skill of the men who make them, partly to the fine quality materials used and lastly to the advanced manufacturing techniques evolved by the Mersey Cables research and development teams (they were the first to give you irradiated cables!) All of which adds up to this: if you're looking for a really tough, flexible, long-life welding cable—look to Mersey. Write, on official letterhead please, for our Leaflet No. I/103 on Welding Cables.



FOR ENDURANCE BEYOND THE CALL OF DUTY



Butt-welding the 3" plates of reactor vessels at Hunterston with Diadem 'Opal' Electrodes.

Photo by Glasgow Evening Citizen

for HUNTERSTON ATOMIC POWER STATION

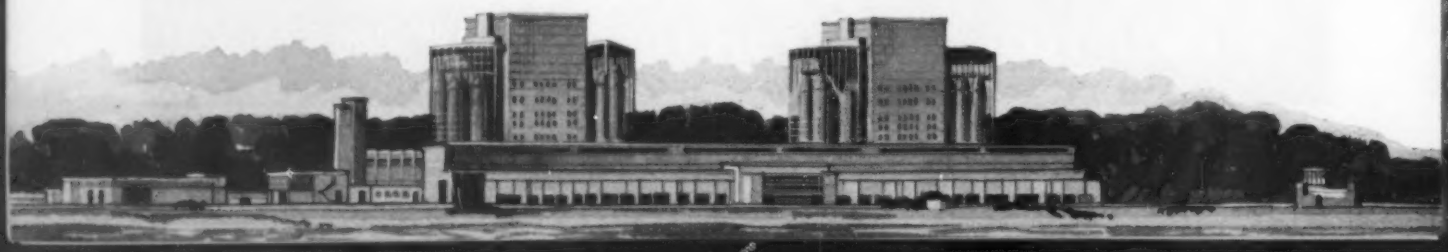
Radiographic inspection is required for every inch of weld and not a microscopic flaw is allowed to go undetected.
Diadem OPAL Electrodes are therefore used EXCLUSIVELY for Site butt welds of the giant Reactor Vessels and also for all Steam Raising Units and Ancillary Ducting.
The OPAL safety factor is *big enough to contain – the atom!*

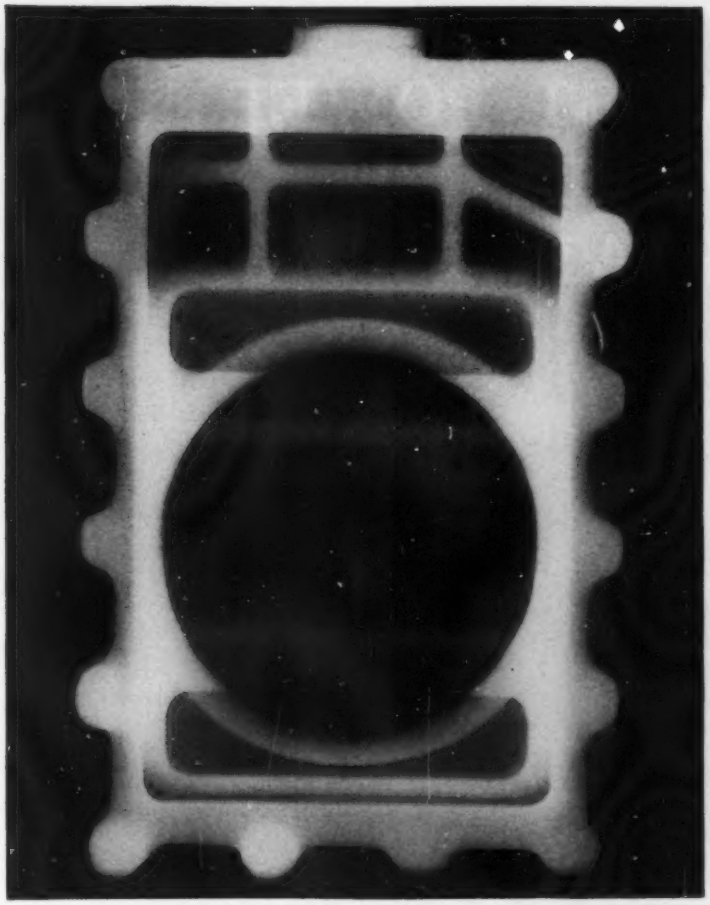
COOPER & TURNER LIMITED
MANUFACTURERS OF RIVETS AND ARC-WELDING ELECTRODES
VULCAN WORKS, VULCAN ROAD, SHEFFIELD 9
Telephone 42091 Telegrams: Rivets, Sheffield

DIADEM

'OPAL' ELECTRODES ARE SPECIFIED BY G.E.C ATOMIC ENERGY DIV.

Hunterston Power Station is being built for the South of Scotland Electricity Board by the General Electric Co., Ltd., in association with Simon–Carves Ltd., Motherwell Bridge & Engineering Co., Ltd., and Mowlem (Scotland) Ltd.





Where sections vary greatly . . .

. . . 2 films are better than 1

ILFORD technicians pioneered multiple film technique in industrial radiography. This has been graphically described as a "sandwich" of two or more films, and the technique gives vastly superior results where specimens with widely varying densities have to be critically examined.

The "sandwich" consists of two or more films of different speeds loaded into a standard cassette for simultaneous exposure. Thick sections of the specimen register clearly on the faster film, and the thinner sections on the slower film. The effects of differential exposure can be accentuated by using lead screens in the "sandwich". The technique can also be used for making duplicate radiographs by using two films of the same speed.

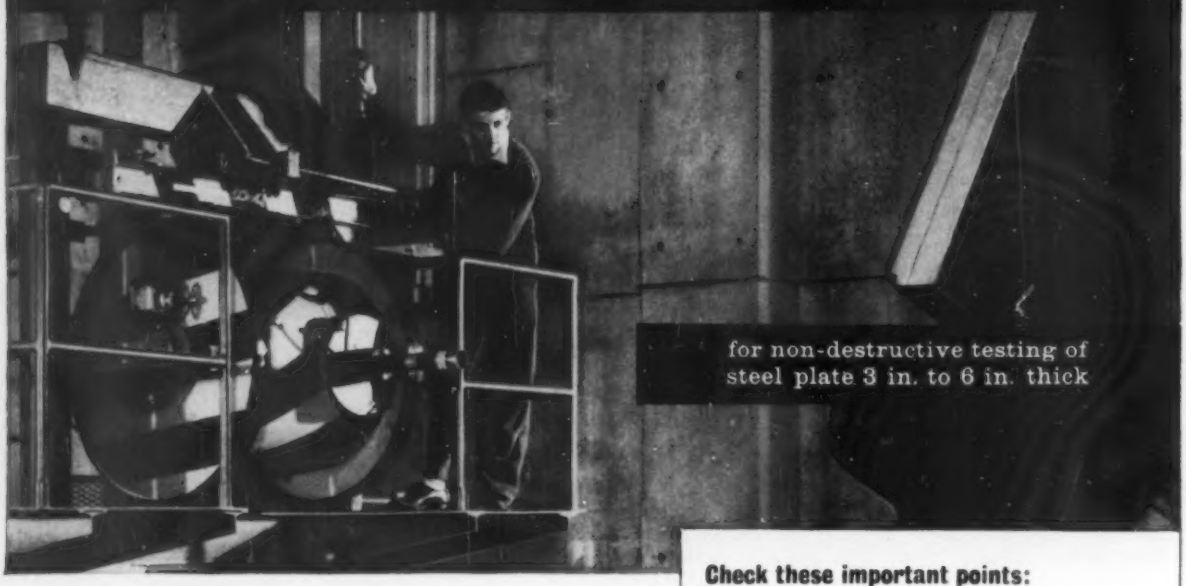
Choice of the appropriate ILFORD Industrial X-ray films obviously depends on the subject, the tube voltage and the presence or absence of screens. Full details of film choice and voltages, as well as lead screens, will be forwarded by request.

For improved radiographic examination

ILFORD INDUSTRIAL X-RAY FILMS, CHEMICALS, CASSETTES AND LEAD SCREENS

ILFORD LIMITED · ILFORD · ESSEX

WORLD'S MOST POWERFUL COBALT 60 RADIOGRAPHIC UNIT



for non-destructive testing of steel plate 3 in. to 6 in. thick

AEI COBALT 60 INDUSTRIAL EQUIPMENT

being set up for radiographic inspection of 4 in welded plates at the works of Whessoe Limited, Darlington, England.

This high intensity cobalt container for non-destructive testing is almost certainly the world's most powerful industrial radiographic unit. It embodies the results of years of experience in related medical equipment of AEI manufacture.

Safe operation, ease of adjustment and robust construction are all provided by a unit which incorporates a source of 2,000 curies for the radiographic examination of welded seams in steel plate up to 6 in thick. Needing only small electric currents for control, and independent of water supplies it is suitable for work on open constructional sites in remote areas.

Check these important points:

POWERFUL The unit provides the equivalent of 3 million volt x-ray testing for 3 in to 6 in steel, with comparable sensitivity and economical exposure times.

SAFE Fully loaded provides ample protection—0.3 milli-roentgens per hour at 1 metre. Source housed in lead and tungsten alloy protective container is easily and safely moved from 'protected' to exposure position by use of the compact control unit.

ACCURATE Beam of radiation 6 in or 12 in wide by 5 ft long (15 or 30 cm by 150 cm) at a distance of 12 ft (360 cm) from source. Special light projector guide beam accurately 'pinpoints' centre of radioactive beam on specimen.

EASILY ADJUSTED Angulating mechanism permits rotation through 350° about both horizontal and vertical axes.

RELIABLE Stout construction and dust-tight, moisture-proof enclosure of container gives reliable operation under adverse conditions and extremes of climate.

AEI **Associated Electrical Industries Ltd.**

Instrumentation Division **Scientific Apparatus & X-Ray Dept.**

132-135 LONG ACRE, LONDON W.C.2

V/X902

INSTITUTE OF WELDING

54 Princes Gate, London, S.W.7

COUNCIL AND OFFICERS

PRESIDENT
E. Fuchs

VICE-PRESIDENTS
W. Barr, o.b.e. G. Roberts H. West

PAST-PRESIDENTS
J. Strong E. Seymour-Semper

HONORARY TREASURER
W. E. Harriss

Chairman of Executive Committee: Dr. N. Gross

Representatives of Industrial Corporate Members

E. F. Burford, m.b.e.	N. L. G. Lingwood	E. S. Waddington
C. Humphrey Davy	J. A. McWilliam, t.d.	Dr. R. Weck

Representatives of Fellows, Members, and Associate Members

D. J. W. Boag	D. C. C. Dixon	S. H. Griffiths
G. M. Boyd, o.b.e.	J. A. Dorrat	D. B. Kimber, o.b.e.
V. W. Clack	R. J. Fowler	T. McIver
F. Clark, m.b.e.	E. P. S. Gardner	H. Martin

Representative of Companions
J. Hooper

Representative of Associates
A. Evitts

Chairman of B.W.R.A. Council
A. Robert Jenkins, j.p.

Chairmen of Standing Committees

Education Committee	Prof. J. G. Ball
Finance Committee	W. E. Harriss
Membership Committee	R. G. Braithwaite
Programme and Publications Committee	J. F. Lancaster
Technical Committee	J. A. Dorrat

Representatives of Branches

Birmingham	W. D. Waller	North London	C. R. Thatcher
East Midlands	—		L. C. Percival
East of Scotland	J. F. Wheeldon	Preston	F. Pilling
Eastern Counties	J. Edwards	Sheffield	W. A. Jenkins, j.p.
Leeds	E. Rose	Southern Counties	J. H. Gillespie
Liverpool	G. A. O. Pridgeon	South London	P. J. E. Heath
Manchester	J. M. Whitworth	South Wales	I. B. Ford
North Eastern (Tees-side)	J. W. Jackson	South Western	A. J. Francis
North Eastern (Tyneside)	R. A. Exton	West of Scotland	J. E. Roberts
		Wolverhampton	S. K. Stokes

SECRETARY
G. Parsloe

Range quality and service second-to-none

Yates Plant offer you the widest and most comprehensive range of manipulative equipment. Every item in that range is made to the highest engineering standards in the Baker Perkins Works at Hebburn on Tyne.

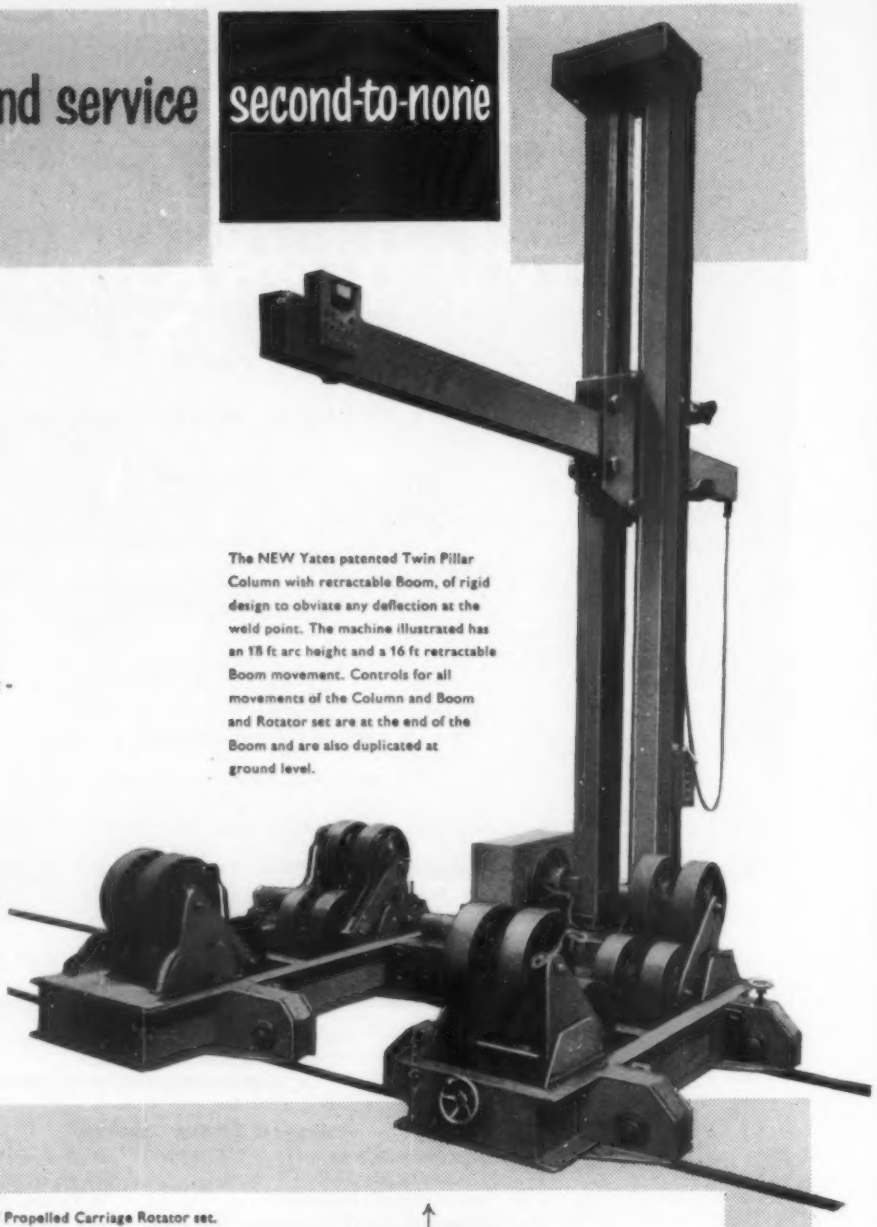
A team, comprising technical representatives and installation engineers, is always at your service - to advise on the most economical and practical equipment, and to ensure that it performs to your entire satisfaction.

For further details please write to:

YATES PLANT LTD.

Bedewell Works,
Hebburn-on-Tyne, Co. Durham.
Telephone: Jarrow 897124

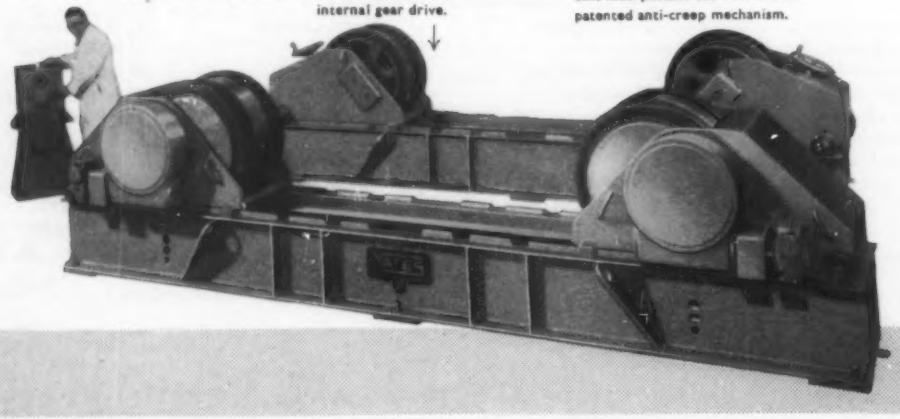
A member of the Baker Perkins Group



The NEW Yates patented Twin Pillar Column with retractable Boom, of rigid design to obviate any deflection at the weld point. The machine illustrated has an 18 ft arc height and a 16 ft retractable Boom movement. Controls for all movements of the Column and Boom and Rotator set are at the end of the Boom and are also duplicated at ground level.

150 ton capacity rotated Self Propelled Carriage Rotator set. With this design the carriages move themselves inwards or outwards to suit any vessel diameter. Note the large projection clearance on the wheels which is achieved by an internal gear drive.

A Yates 20 ton Travelling Self-aligning Rotator set with integral bogies. The idler unit incorporates the well known patented anti-creep mechanism.



BRITISH WELDING RESEARCH ASSOCIATION

19 Fitzroy Square, London, W.1

COUNCIL AND RESEARCH BOARD

PRESIDENT

SIR CHARLES S. LILLICRAP, K.C.B., M.B.E.

CHAIRMAN OF COUNCIL

A. ROBERT JENKINS, J.P.

HONORARY TREASURER

W. E. HARRISS

MEMBERS OF COUNCIL

SIR DONALD BAILEY, O.B.E., J.P.
PROF. J. F. BAKER, O.B.E., F.R.S.
DR. R. BEECHING
D. J. W. BOAG
J. BROWN
DR. T. W. F. BROWN, C.B.E.
C. HUMPHREY DAVY
C. H. FLURSCHEIM
E. FUCHS
T. M. HERBERT
E. J. HILL
F. C. S. L. LEWIN-HARRIS
H. PEARSON LOBNITZ
SIR ANDREW MCCANCE, F.R.S.
RICHARD MILES
J. MITCHELL, C.B.E.
PROF. SIR ALFRED PUGSLEY, O.B.E., F.R.S.
L. ROTHERHAM
R. B. SHEPHEARD, C.B.E.
C. M. SPIELMAN, O.B.E., M.C.
T. STEVENSON
J. H. N. THOMPSON, M.C.
LT.-COL. J. F. TODHUNTER
W. T. TOWLER, J.P.
DR. M. A. VERNON
DR. E. G. WEST
J. M. WILLEY

RESEARCH BOARD

DR. E. G. WEST (*Chairman*)
DR. N. P. ALLEN, F.R.S.
PROF. G. WESLEY AUSTIN, O.B.E.
PROF. J. G. BALL
W. BARR, O.B.E.
DR. L. E. BENSON
DR. J. S. BLAIR
DR. N. BOOTH
E. P. S. GARDNER
A. H. GOODGER
DR. NICOL GROSS
DR. H. K. HARDY
DR. H. HARRIS
A. ROBERT JENKINS, J.P.
DR. N. J. L. MEGSON
J. D. D. MORGAN
DR. W. I. PUMPHREY
DR. L. REEVE
G. ROBERTS
PROF. E. C. ROLLASON
DR. H. SUTTON, C.B.E.
J. TURNBULL
DR. J. H. WEAVING
L. M. WYATT

DIRECTOR OF RESEARCH

DR. RICHARD WECK

SECRETARY

A. O'NEILL

Fine Wire Welding with the 'Quasi-Arc' LYNX and new ST.2 TORCH

NEW GAS-SHIELDED BARE-WIRE EQUIPMENT FOR MILD STEEL*

The revolutionary ST.2 arc welding torch is new, it's sleek, efficient, and a pleasure to handle. The ST.2 is the production man's short cut to greater efficiency and lower welding costs. With this tool and the well-known LYNX wire feed equipment *you can now weld mild steel semi-automatically:—*

- **In any position**—flat, inclined, vertical (up or down), and overhead.
- **Down to 20 swg. sheet**—and for thick plate as well. (Wide gaps can be tolerated.)
- **Four times as fast**—on thin sheet compared with other methods.
- **Economically**—high welding speeds—fine wire on large spools—inexpensive gas shielding—all add up to big cost reductions.
- **With minimum distortion**—and easily controlled penetration.
- **Easily**—using the featherweight torch, LYNX wire feed unit, and specially designed slope-controlled rectifier; with shielding by CO_2 or Argon gas mixtures.

* ST.2 welding for stainless steels too, with Argonox shielding. For full details write for TC.207.

THE BRITISH OXYGEN COMPANY LTD
Quasi-Arc Works, Bilston, Staffordshire. Tel: Bilston 41191

BRITISH WELDING JOURNAL

OFFICIAL JOURNAL OF THE INSTITUTE OF WELDING AND THE BRITISH WELDING RESEARCH ASSOCIATION

Incorporating the *TRANSACTIONS* of the Institute and *WELDING RESEARCH*

DECEMBER 1960
Volume 7 Number 12

Subscriptions
Members free:
Extra copies at 7*s.* 6*d.* each
Non-Members:
£5 per annum
Single copies 10*s.* each

Published Monthly

Editor-in-Chief: G. PARSLOE, M.A.
54 Princes Gate, London, S.W.7
(Knightsbridge 8556)

Executive Editor:
C. ROWLAND HARMAN, B.Sc. (Eng.)
Editech
77a Chertsey Road
Woking, Surrey
(Woking 5838)

Advertisement Manager:
G. S. HARTLEY
54 Princes Gate, London, S.W.7
(Knightsbridge 8556)

Note: Editorial contents copyright. The Institute of Welding and the British Welding Research Association do not hold themselves responsible for statements made or opinions expressed in articles appearing in this Journal.

CONTENTS

INSTITUTE OF WELDING

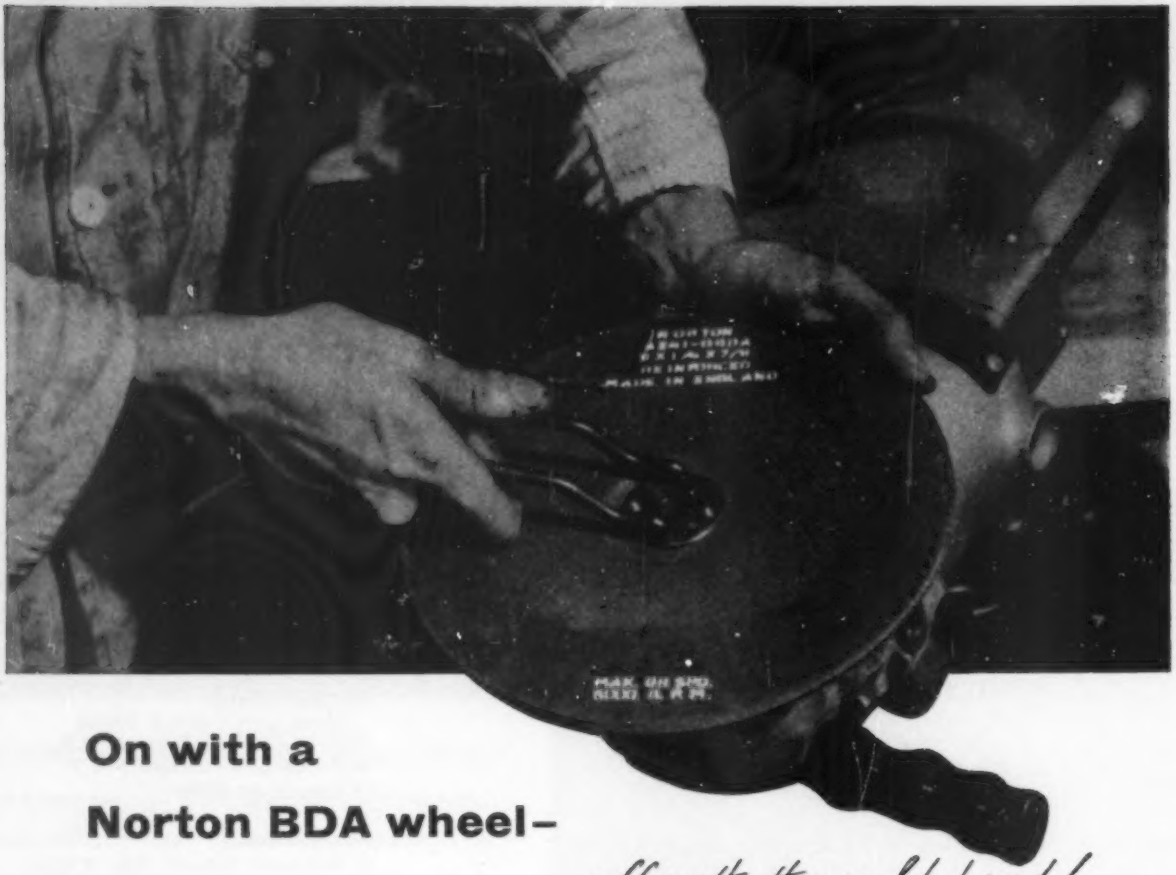
693 **The Problem of Welding High-Temperature Service Materials**
By E. Kauhausen, P. Kaesmacher, and S. Sadowski

708 **Hot Pressure Welding of Titanium**
By C. F. Wilford and R. F. Tylecote

713 NEWS AND ANNOUNCEMENTS

The Institute of Welding 54 Princes Gate, London S.W.7

British Welding Research Association 19 Fitzroy Square, London W.1



On with a Norton BDA wheel–

off with the weld bead!

This 9″ × ¼″ × ⅞″ depressed centre wheel is a Norton A241-QBDA reinforced resinoid wheel. It is mounted and ready now to cut into its work with speed *and* safety because it is doubly reinforced with a strong integral fabric and a tough additional safety web.

They're versatile, these Norton BDA Reinforced Wheels. Use them for cleaning up, bevelling, cutting down, and smoothing (for cutting-off specify the thinner BD type). Roughing and finishing, tough Norton Reinforced Wheels will do a sturdy job – and do it with the utmost speed and economy.

In the Norton range of wheels – over 100,000 sizes, shapes and specifications – there is one that is exactly right for your job. Let your Norton or Alfred Herbert representative help you select it, and if you want it for weld grinding, cleaning up and the multitude of jobs you do with your portable right-angle grinder, it will probably be a Norton BDA or BD reinforced resinoid wheel.

Get through more work with Norton Abrasives

*

NORTON ABRASIVES

NORTON GRINDING WHEEL COMPANY LIMITED

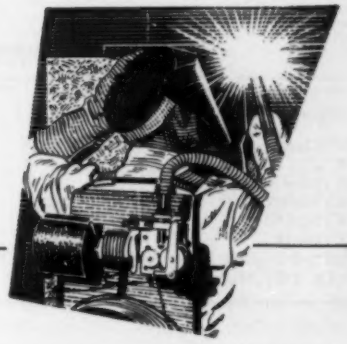
Welwyn Garden City, Herts. Telephone: Welwyn Garden 3484 (15 lines)

Enquiries also to: **ALFRED HERBERT LIMITED, Coventry** · Telephone: Coventry 89221

NORTON and BEHR-MANNING factories also in Argentina, Australia, Brazil, Canada, France, Germany, Italy, Northern Ireland, South Africa and U.S.A.

* *Trade mark of Norton Company U.S.A. the world's largest manufacturer of abrasive products* N.G.W. BDA. 158

Welding
TECHNOLOGY



The Problem of Welding High Temperature Service Materials

By E. Kauhausen, DIR.DR., *P. Kaesmacher*, DIPL.ING., *S. Sadowski*, CHEM.ING.

The paper refers firstly to investigations on the welding of ferritic steels for high-temperature service, containing 1·0–9·0% Cr and 0·5–1·0% Mo, and describes the properties of joints made by various welding processes.

The differences between basic lime-coated and acid rutile-coated electrodes are examined, particularly in respect of their welding characteristics and economy. The need for proper preheating of the base material and subsequent stress-relief heat treatment of the welded joint is discussed.

The welding of 12% Cr steel is then examined, and it is shown that by the use of electrodes with similar composition to that of the base material and by close attention to the heat-treatment procedure satisfactory welded joints can be produced.

In welding fully austenitic stabilized steels, cracking is a considerable problem, and its causes are investigated. It is shown that high quality welds can be produced by using special 16% Cr–13% Ni–6% Co electrodes which produce a stabilized deposit.

In the final section of the paper the possibilities of welding austenitic and erritic steels with nickel alloy electrodes are discussed.

ELEVATED temperatures and high pressures are the most pressing demands of industrial progress in the sphere of energy and heat production, chemical high pressure synthesis, oil refining, and also in the field of steam turbine, gas turbine and waste-gas turbine construction.

Low costs per kWh and high efficiency result from the high temperatures and pressures at which modern high-pressure steam generators now work. The high pressures and temperatures used in the oil industry and in the field of high-pressure chemical synthesis have resulted in increased efficiency and the manufacture of new products which could not be produced in any other way. Waste-gas turbines working at high temperatures bring about an appreciable increase in the efficiency of diesel motors. These trends towards industrial progress have been carefully studied in Germany and remarkable results have been achieved.

The work in the fields already mentioned that the constructors of modern plant have carried out during recent years has been largely dependent on the availability of metallurgical materials which could meet the increased demands made upon them. Likewise it was just as important to study the problem of welding these new materials and to develop the necessary filler materials needed for the various welding processes. The technical processes used in the welding of these materials also had to be studied, especially in the industrial fields already mentioned where the construction

Manuscript received 18th December 1959.
The authors are with Böhler Bros. & Co., Düsseldorf.

Table I

Composition of ferritic high-temperature constructional steels

Type of Steel	*Analysis, %*					
	C	*Si*	*Mn*	*Cr*	*Mo*	*V*
13CrMo44	0·15	0·30	0·4–0·6	0·8–1·0	0·45–0·55	—
0·4%Cr; 0·8%Mo; 0·3%V	0·15	0·30	0·4–0·6	0·3–0·4	0·70–0·85	0·25–0·30
10CrMo910	0·10	0·30	0·4–0·6	2·0–2·5	0·90–1·10	—
10CrSiMoV7	0·10	1·0–1·2	0·4–0·6	1·6–2·0	0·25–0·30	0·25–0·30
12CrMo195	0·12	0·30	0·4–0·6	4·0–6·0	0·45–0·65	—
12CrMo195+Si	0·12	1·2–1·4	0·4–0·6	4·0–6·0	0·45–0·65	—
7%Cr, 0·5%Mo	0·12	0·50	0·4–0·6	6·0–8·0	0·45–0·65	—
9%Cr, 1·0%Mo	0·12	0·50	0·4–0·6	8·5–9·5	0·90–1·10	—

of plant without the use of welding techniques is out of the question.

Ferritic Steels

Table I lists the ferritic steels whose welding problems will first be dealt with. Austenitic materials will be treated at a later stage. It is important to note that this group of ferritic steels is characterized by their increased Cr contents. All are alloyed with Mo and some with V also, and all are air hardening. This fact is of primary importance in welding, for although the steels have good welding properties they are, like many heat-treatable steels, subject to hardening and embrittlement not only in the transition zone but also in the weld deposit itself as a result of their particular structural compositions. Measures must therefore be taken to eliminate hardness peaks and to prevent the formation of cracks. During welding weld cracks and underbead cracks may form; after welding also stress cracking may take place and under certain circumstances extensive fissuring may occur.

It is well known that an increase in the carbon content of a steel always increases its tendency to air hardening. Therefore to keep the welding problems (as seen from the steel aspect) at a minimum, these steels have been manufactured with a maximum content of 0·5% C (see Table I). For many of these alloys however the carbon content has been limited to 0·10% and 0·12% respectively.

This fact, together with the necessary preheating during the welding process and subsequent heat treatment, enables all the ferritic steels listed to be welded successfully without complications.

The following processes can be used in the welding of these steels: autogenous, argonarc, and metal-arc welding and of recent times also the inert-gas metal-arc and submerged-arc processes.

Experience in Germany of the CO_2 welding of both ferritic and austenitic steels for high-temperature service has not been extensive enough for basic rules to be formulated.

In general, automatic welding finds little application in the field under discussion except, for example, in the welding of boilers and turbine shafts. Manual welding still plays the major role in fabrication.

The medium alloys with up to 9% Cr, as shown in Table I, are weldable using the submerged-arc process, which is particularly applied to those containing 1%, 2·25%, and 5% Cr.

In the case of boiler construction, for example, the root weld of the J-groove is filled by the argonarc process or with a suitable basic lime-coated electrode. The preheating temperature used is based on the heat-treatment data of the steel to be welded. Materials similar to that of the base metal are used as filler wires. As far as Si content is concerned it is important that the alloy content of the welding material should be at the maximum limit permitted by the analysis. In this way small losses arising out of 'burn-out' may be compensated.

Submerged-arc welding

The powders used for the submerged-arc welding of low- and medium-alloyed steels are UM 80, UM 90, and of recent times also Grey H, supplied by the Linde Company of Germany. They are all powders melted in glass form. UM 80 and UM 90 are acid materials with approx. 35% of SiO_2. Grey H is a welding powder with a low silica content. In the case of UM 80 powder the alkaline earth content is high whereas UM 90 contains more manganese oxide. UM 80 gives less Si 'pick-up'. When using UM 90 welding powder a 'pick-up' of Mn must be anticipated.

UM 90 powder is generally used for welding the circumferential seams of boilers whereas the longitudinal seams are usually welded with UM 80 powder, which provides somewhat better mechanical properties. In this connection it should be mentioned that with Grey H powder the notch impact values are somewhat higher than those obtained when UM 80 or UM 90 are used.

An important point to be observed during welding is to ensure that the current selected is not too high. A suitable value is 700–800 amp with an arc voltage of about 30 V. After welding, the seams are usually not normalized but are subjected to a tempering treatment. The same applies when metal-arc welding is used. Naturally they can also be normalized, although this is more expensive and, in the case of large sections, often impossible. The tempering temperatures are 680°–720°C. for 1% Cr steels and 730°–750°C. for 2·25% Cr steels. The period of treatment is 1 hr per 25 mm thickness of material.

Using the method described, boilers with wall thicknesses of 40–100 mm are regularly being produced. Even welding operations involving the joining of wall thicknesses of 186 mm have been successfully carried out. Table II shows the mechanical properties of such welded joints carried out on 2·25% Cr and 1% Cr steels.

The steel with 0·8% Mo, 0·3% V, and 0·4% Cr is

Table II

Mechanical properties of welds in ferritic high-temperature steels

Welding Process	*Type of Steel*	*Yield Point, kg/sq.mm*	*Rupture Strength, kg/sq.mm*	*Elongation, %*	*Notch Impact Strength, mkg/sq.cm*
Submerged-arc	10CrMo910	48–53	60–65	—	9–11 (top layer 7–8)
Submerged-arc	13CrMo44	43–45	52–57	—	10–12
Submerged-arc	0·8Mo–0·3V–0·4Cr	66–70	70–85	17–18	7–13·5
Inert-gas metal-arc	10CrMo910	50	64·5	21	15

little used in Germany, although it seems to be used quite extensively in Britain. The following procedure was used in the welding of 55 mm thick material using the submerged-arc process. The base material was preheated to 300°–400°C., and two runs were laid in the weld root using *basic* lime-coated electrodes. The weld was then completed, using UM 80 powder. Tempering was then carried out for 6 hr at a temperature of 660°–680°C. The mechanical properties of the joint so produced are given in Table II.

Inert-gas metal-arc welding

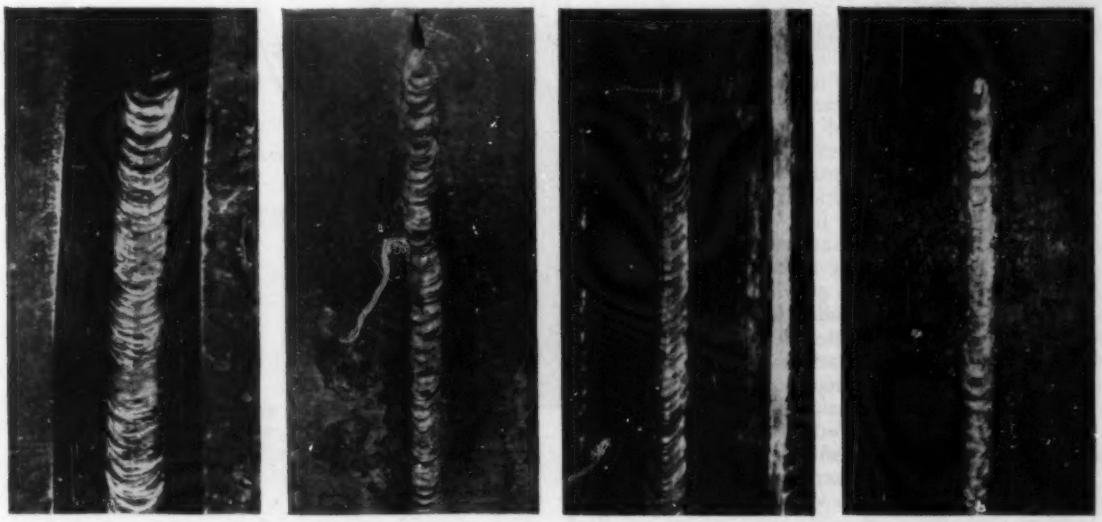
Ferritic materials of the Cr–Mo group can also be welded by the inert-gas metal-arc (Mig) process. In this case the use of argon gas with 3% oxygen is most suitable. It has further been shown that to obtain improved welding results filler wire of similar composition to that of the base metal but with a somewhat higher Si content of about 0·4–0·5% is most suitable.

The following example deals with the welding of a square container for a hydrogenation plant. Such welding applications are far more critical than those carried out on drums, because the weld is subject to complex axial stresses at the corners. During the operation the 2·25% Cr steel, having a wall thickness of 40 mm, was preheated to 200°–250°C. This relatively low preheating temperature was off-set by the high degree of heat induced into the metal during welding with the Mig process. The subsequent tempering was carried out at 750°C.

The mechanical properties of test pieces taken from the weld joint are shown in Table II. Metallurgical complications did not arise during welding, but there were occasional faults resulting from short-comings of the apparatus used. Pores which suddenly appeared in the weld were found to be due to leakages in the water cooling jacket of the welding gun, although the amount of water vapour generated could not usually be ascertained visually. With modern apparatus such difficulties are eliminated, for the welding guns are provided with inter-changeable tips which are not water cooled.

Gas welding

Autogenous welding is largely limited to the joining of thin-walled tubes up to 6 mm thick. From the metallurgical viewpoint the process is the most unsatisfactory welding method because it is practically impossible to control exactly the composition of the deposited weld metal, and in this of all welding processes the results are largely influenced by the skill of the welding operative. Experience has shown that



1—*Argonarc root welds on tubes*

autogenous welding is usually only applied to steels having a Cr content of up to about 2·5%.

Argonarc welding

Of recent years the argonarc process has become of ever increasing importance for depositing root welds. For this purpose J-grooves are usually prepared. As opposed to coated electrode welding, argonarc welding is usually carried out without a root gap, except in the case of V-welds. The process calls for special skill on the part of the welding operative (*see* Fig. 1).

Using this method however it is possible to make root welds on tubes which are of such a high standard that the reverse side of the weld appears to have been thinly back-welded. In argonarc welding gas flushing, usually with a mixture of 15% H_2 and 85% N_2, plays an important part in the production of smooth welds, as may be seen from Fig. 1.

Manual welding

For thick material multi-layer welding with electrodes is used, but the work should be carried out only by welders who are fully qualified to weld the types of steel involved.

Selection of filler materials

The real problem connected with the welding of the high-temperature steels listed in Table I is the selection of the right filler materials, for the analysis of the weld deposit should be similar to that of the base metal. This is true at any rate where only one of the steels listed has to be welded. But if steels of different chemical composition have to be welded together then a filler metal should be selected which deposits metal similar in chemical composition to that of the lowest alloy of the two steels to be welded (this is specially important in respect of the Cr content).

Welding with austenitic electrodes of the 25/20 or 18/8 types on such ferritic Cr steels is not to be recommended. In practice such welds are subjected to high temperatures and the different coefficients of expansion of the weld and base metals may lead to additional stresses building up, either in the weld seam itself or in the transition zone. It is recommended that austenitic electrodes should be used only where a subsequent heat treatment cannot be carried out; for example, on the building site or for repair work.

For the welding of ferritic Cr and Mo alloyed steel both rutile type and basic lime-coated electrodes may be used. Any additional precautions which have to be taken are governed by the type of electrode selected. Until now, preference has generally been given to the use of acid rutile electrodes because their welding properties are usually better than those of the basic lime type. On the other hand the mechanical properties of acid rutile weld deposits are not as good as those obtained from basic lime electrodes. When welding with rutile electrodes it is essential that the complete heat treatment should be fully carried out, although for large sections or steels with an increased alloy content it is often very difficult to carry out the correct preheating and subsequent tempering. Such conditions are often met with on the construction site, and cracks often occur. Such problems do not arise when basic lime-coated electrodes are used, even when the heat treatment has been inadequate, for the mechanical properties of the deposits, especially elongation and notch impact, are much superior.

Table III

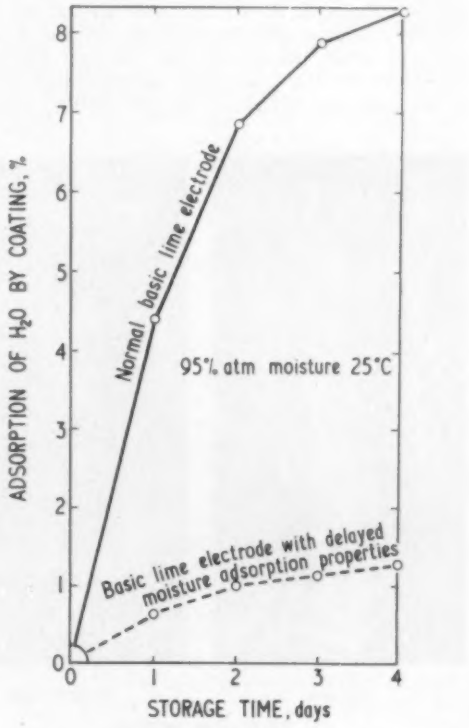
Hydrogen contents in weld deposits

	Class of Electrode				
	No. 1	*No. 3*	*No. 5*	*No. 6*	*Uncoated*
Hydrogen, ml/100 g*	12·2	11·4	12·0	3·6	0·2

* Volume diffusing out of weld deposit in 48 hr at 20°C.

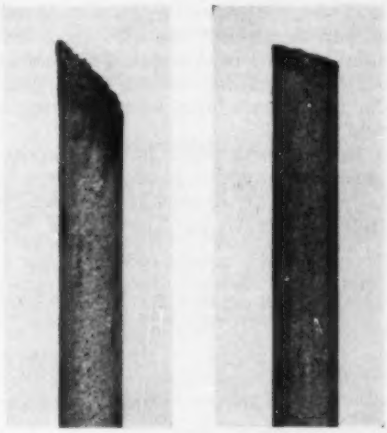
Table III shows a further inherent disadvantage of rutile electrodes, namely the high hydrogen content of the weld deposit. In this connection it should be noted that hydrogen escapes at a slower rate from Cr–Mo alloyed steels because its diffusion rate is noticeably reduced by the alloying elements. Taken in conjunction with other factors, such as the rate of cooling and the effect of external stresses, hydrogen plays a major part in the formation of cracks in welds made with acid rutile electrodes.[1,2]

Recently, the practice of using basic lime electrodes of a similar grade to that of the base metal has gained in popularity. This is especially true in Germany on large projects involving the construction of boilers or pipe lines. The first point in their favour is their ability to produce superior mechanical properties; in addition, the weld deposit has a low hydrogen content

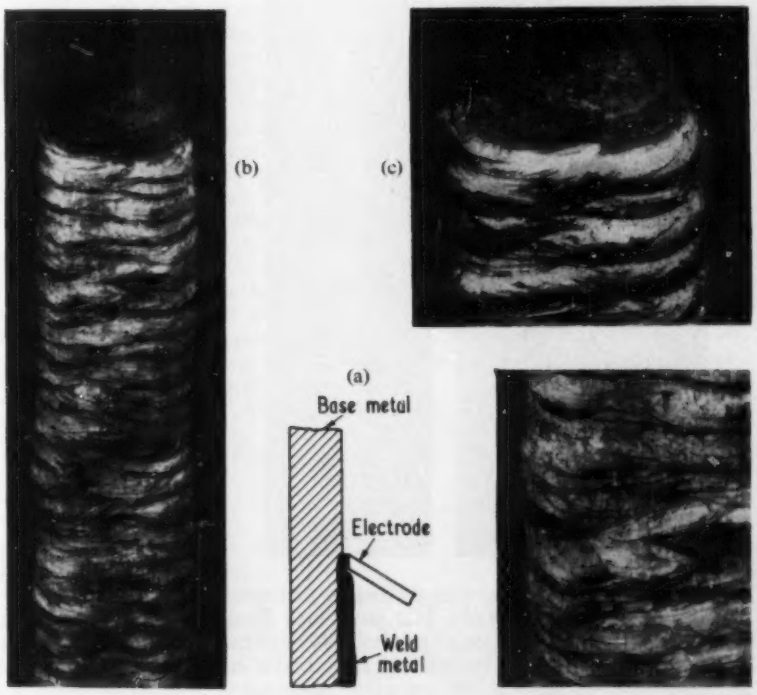


2—*Absorption of water by basic lime electrodes. (95% atmos. moisture at 25°C.)*

(c)



3—*Melt-off shape of* (a) *Old type basic lime electrode;* (b) *new development;* (c) *welding position*



4—"*Flushing effect*" *of well-positioned electric arc*

(*see* Fig. 2). Secondly, through the recent introduction of moisture-repellent additions to the electrode coating, the storage properties of basic lime electrodes have been improved, and likewise the safety factor in welding in regard to the gas content of the deposited metal has also been increased.[3]

But one of the most significant reasons for the increase in the consumption of basic lime electrodes is that improvements have been made in their welding properties which have made them easier to handle. Firstly, a constant rate of melting of the coating has been achieved by controlling the melting temperature within the coating.

Figure 3 shows how the old type of basic lime electrode showed a strong tendency to form a 'scoop', making it difficult for the welder to handle the

electrode. The result is that a much too convex deposit is formed and the sides of the weld show insufficient penetration into the base metal. The coating of the new basic lime electrodes shows a constant rate of melting in all positions, even when the enclosed angle of the weld is small.

When welding with basic lime electrodes in abnormal positions it appears to be necessary to increase the stability of the arc, especially when welding high-temperature service steels. The arc of basic lime

5—Weld in 35 mm thick, 2·25% Cr–1·0% Mo tube, 180 mm bore, made in 6½–8½ o'clock position

(a)

(b)

(c)

electrodes is often unstable, it easily breaks, and when the arc is restruck it is possible that pores may form. The length of ionization within the atmosphere of the arc must be influenced in such a way as to make the arc more fluid. In this way the arc would remain unbroken even when the electrode was withdrawn more than usual from the base metal. Apart from this feature the proper positioning of the electrode is also important, for this ensures that the base metal is sufficiently melted (Fig. 4). A flushing effect is thus created, which is advantageous especially when welding in abnormal positions, for any slag that is left is thereby remelted. The diagram, Fig. 4*a*, explains more fully what is meant. Figure 4*b* shows a vertical fillet weld and Fig. 4*c* indicates that the base metal has been melted to a sufficient depth. The subject of penetration is intentionally avoided because it is often associated with under-cutting; yet a feature of this flushing is a relatively pronounced degree of melting of the base metal without the creation of under-cutting.

This newly developed basic lime electrode therefore has a somewhat hotter melting characteristic, which ensures that the metal transfer from the electrode to the base metal is carried out at a higher rate and that the particles themselves are finer. The melt itself and the slag are relatively more easy flowing, although the weld metal solidifies fast enough for the electrodes to be used in all positions. For example, root welds can be made in all positions with 2·5 mm dia. basic lime electrodes and will stand up to X-ray examination. This indicates that good penetration can be obtained. For such root welds it is best to use the electrode in the position shown in Fig. 5.

It must be emphasized that, despite the easy flowing properties of the melt, the build-up properties of the weld itself are not affected, and very thick passes can be made. The time needed for the removal of slag is thus reduced.

A further major advantage of basic lime electrodes is their high degree of deposit efficiency—115% as against the 95% obtained with rutile electrodes (*see* Table IV).

Finally, the melt-off rate of the newly developed Cr–Mo alloyed basic lime electrodes is somewhat higher than that of acid rutile electrodes of the same type. This was demonstrated by tests that were carried out in the welding shop by two qualified pipe welders. The actual welding times and secondary times were measured exactly by stop-watch, but preparation times were omitted because they were dependent on conditions existing locally in the respective welding shops. The object of the operation was to make a comparison between the technical welding properties of the two types of electrode. The results in Table IV show that by using basic lime-coated electrodes a time saving of 20% can be obtained. From our experience it may be said that in the welding of high-temperature service steels rutile electrodes should be used only for the welding of wall thicknesses up to 12 mm. In all other cases it is advantageous to use basic lime electrodes.

Table IV

Deposit efficiencies of electrodes on 13CrMo44 pipes of 40 mm wall thickness, 220 mm bore

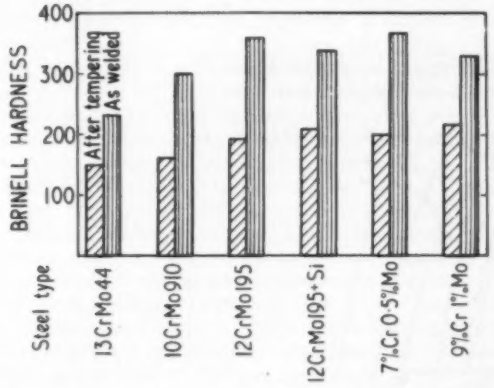
	Type of Electrode	
	Rutile	*Basic Lime*
Melting time at 160 amp; dia. 4/350 mm	1·17 min	1·11 min
Productivity	95%	115%
Melting time for 1 kg weld deposit	63 min	48 min
Welding time including time for slag removal and electrode changing for 1 kg of weld deposit	94 min	73·5 min
Proportion of time required for slag removal and electrode changing	33%	35%

Heat treatment

A further factor governing the successful production of weld joints is the proper application of preheating

and subsequent heat treatment. As a general rule preheating temperatures should not be less than 200°C., and as the Cr content and wall thickness increase the temperature should also be raised to about 400°C. It is also important that the selected preheating temperature should be held during the course of the welding operation.

Subsequent heat treatment of ferritic high-temperature service steels should be carried out directly after welding because, despite preheating, the weld deposit itself and also the transition zone and the heat-affected zone tend to acquire a hardness greater than that of the original steel (Fig. 6). Whereas the steels sometimes become exceedingly hard if no subsequent heat treatment is carried out, the right treatment reduces the



6—*Brinell hardness in transition zone of welded Cr–Mo high-temperature steels*

hardness at the weld to roughly the same relatively low Brinell values as the rest of the material, despite variations in the Cr content.

In general, subsequent heat treatment for 1½% Cr–Mo steels consists of annealing at 720°C. This temperature is raised to 750°C. for 2–3% Cr steels, and for high-temperature service materials having a Cr content of 5–9% post-weld heat-treatment must be carried out at 760°C. These values are somewhat higher than those quoted by Bystram,[4] for it is considered that if the formation of a hardened zone in the weld deposit and transition zone is to be prevented then higher preheating temperatures must be applied. This is especially true in the case of horizontal welding carried out on vertical walls where a straight weld is made. If a low preheating temperature drops only a little during the course of welding there is a danger of cracks forming. In the case of subsequent heat treatment somewhat lower temperatures than those given may prove to be sufficient. In Germany however the Material Surveying Agencies insist that the weld joints should not exceed a certain hardness, and the safest way of ensuring this is to use the higher heat-treatment temperature. Only in this way can it be assured that a fairly stress-free state exists within the weld joint. Additional exterior stresses can then no longer cause damage.

The length of the annealing period depends on the wall thickness of the material—approx. 1–1½ hr per 25 mm thickness. The width of the heated zone for such treatment must be at least 6 times the thickness of the plate on either side of the weld and never less than 50 mm. It is also important that the weld should be left to cool down slowly after treatment, either in the furnace or under suitable insulating material.

12% Chromium Steels

The steels described have a maximum operating temperature of 530°–550°C. Above this temperature not only their creep resisting properties and characteristics but also their resistance to scaling undergo certain changes. To widen the field of application for creep-resisting steels above this temperature limit research work has been carried out on alloys having a 12% Cr base (Table V).

A steel with such a composition is far better than those already mentioned in respect of its resistance to scaling. Creep test values have also been obtained which are between those of ferritic high-temperature service steels and austenitic steels, both in regard to temperature and load (Fig. 7).

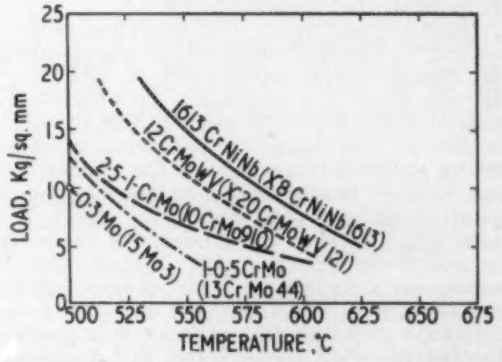
Table V

Composition of 12Cr1Mo VW steel

Analysis, %							
C	*Si*	*Mn*	*Cr*	*Ni*	*Mo*	*V*	*W*
0·20	0·25	0·50	11·5–12·5	0·60	0·90–1·10	0·30	0·50

The curves in Fig. 7 demonstrate the superiority of stabilized austenitic steels as compared with the ferritic steels already discussed. Between these two groups there is the 12% Cr steel whose creep resistance has been noticeably increased by the addition of carbide-forming elements such as W, V, Mo. But the creep resistance rapidly falls off at a temperature of 600°C., so that the application of this alloy at high loads must be restricted to a range of temperature up to 580°C. In the 530°–580°C. temperature range the mechanical properties of the 12% Cr steel bridge the gap between the normal heat refined steels and austenitic steels.

Attempts at expanding the range of application of the creep-resisting steels for temperatures above 550°C. has been largely influenced by the high price of



7—*Creep resistance of various high-temperature steels (10^5 hr)*

Ni-alloyed steels. At present, the 12% Cr steel is used quite extensively in Germany, so that some of the welding problems to which it gives rise will be discussed.

Heat treatment

With manual metal-arc welding the weld deposit, when cooled in a still atmosphere, has a hardness of 460–520 D.P.N. A weld joint of such hardness is very prone to cracking.

With continuous cooling the martensite point lies at about 260°C. At a cooling rate of ½–1 hr the bainite transformation, coupled with an increase in hardness, commences at approximately 400°C. During welding a preheating temperature of at least 400°C. must be held so that the material is kept out of the transformation phase, and for safety reasons a preheating temperature of 450°C. has been laid down. From the TTT diagram (Fig. 8) a stress-relieving temperature of not more than 780°C. can be selected, for at higher temperatures ferrite starts to form.

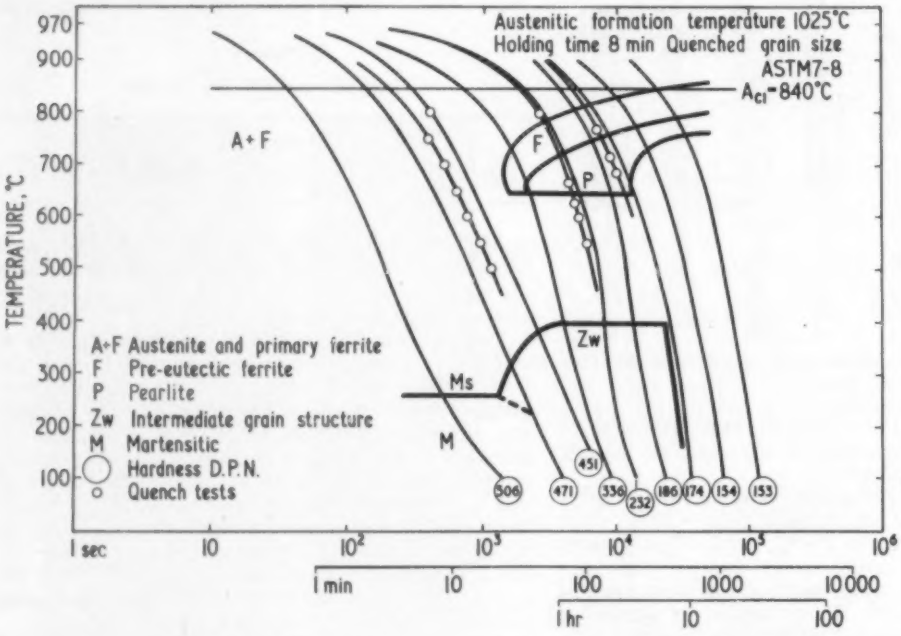
Research has shown that annealing cannot be carried out directly from the preheating temperature, for then the notch impact values (D.V.M.) amount to only about 1–2 mkg/sq.cm. To obtain a good degree of toughness it is essential that the weld be cooled to well below the preheating temperature before annealing is commenced. The material should not, however, be allowed to cool down to room temperature otherwise stress cracks may appear. This is especially true when the thickness of the material exceeds 30 mm. Cooling to 250°, 200°, or 180°C. with subsequent annealing also fails to raise sufficiently the notch impact strength and there is a transformation of the residual austenite. It is possible to increase the notch impact values to 5–8 mkg/sq.cm only by cooling to a temperature of 150°C., holding for a period of 1–2 hr and then annealing. The rupture strength obtained is then approx. 80 kg/sq.mm and the elongation value 15–17%. Sections of 12% Cr steel having a wall thickness of more than 10 mm should therefore be allowed to cool to approx. 150°C. after welding, and held at this temperature for about 1–2 hr before annealing is carried out. In this way stress cracking can be avoided. A suitable temperature is 750°–770°C., and annealing should extend over a period of 5–7 hr according to thickness.[5]

As is the case in the welding of all high-temperature service steels accurate measurement of the preheating and annealing temperatures is essential. If no thermocouple is available for this purpose then at least a temperature-indicating crayon should be used.

In an example where 3·5 mm thick pipe supports were welded to a collector, having a wall thickness of 22 mm, the following heat treatment was carried out. The inside of the collector was preheated to 350°C. and this temperature was held throughout the welding operation. During pauses measures were taken to ensure that this temperature did not drop below 150°C. Annealing was carried out for 3–4 hr at a temperature of 740°–760°C.

In the same welding shops a 12% Cr steel with a wall thickness of 8 mm was preheated to 150°C. The root weld was laid by means of the argonarc process, and all subsequent passes were made using 3·25 mm basic lime electrodes. After the section has been allowed to cool to room temperature it was annealed for 3 hr at a temperature of 740–760°C. without cracks forming.

When welding 12% Cr steel sections with wall thicknesses of over 30 mm, and where weld seams converge, as well as when there are areas with cross sectional variations where multi-axial stresses could occur, it would not appear to be desirable for the whole of the



8—TTT diagram

weld to be filled in without a break. For safety reasons a third of the weld should be completed and then cooled off and annealed in the manner described. When, at a later stage, the weld is completed the maximum stresses will not be so high that they could lead to cracking.

All these methods undoubtedly bring with them additional expenditure on the part of the manufacturers, for they require additional heat-treatment capacity and more labour.

Austenitic Steels

The working temperatures of some modern high-pressure steam boilers now lie in the region of 600°–650°C. with working pressures of 150–350 times atmospheric pressure. In stationary gas turbines and waste-gas turbines the working temperatures have been raised to 700°C. As the tensile properties of the Cr–Mo group of steels (up to and including the 12% Cr steels) are inadequate for such applications austenitic materials have to be used (*see* Table VI).

Since about the year 1951 work has been going on in Germany in this field, the original inspiration for the work coming from the USA. From the start however, as opposed to the trends in America, no austenitic steels with ferrite contents on the 19/9 Cr—Ni basis were used in Germany. An important factor influencing the choice of fully austenitic steels was their improved mechanical properties at elevated temperatures. For working temperatures in the 600°–700°C. range creep values were improved by the addition of Nb.

Apart from the need for good creep-resistance properties applications often require a high degree of resistance to inter-crystalline corrosion. In fully austenitic material this quality is essential for all applications where, during the starting up or running down stage, a fluid phase is involved. This is the case, for example, with high-pressure boilers and in chemical plant. The adoption of this policy avoided the setbacks arising out of inter-crystalline corrosion which were experienced when 19/9 Cr—Ni plates were used in the early stages of development.

The danger from stress corrosion is not too great with the Cr–Mo steels, and the tendency towards stress corrosion diminishes as the Cr content of the material increases. The austenitic steels are however more susceptible in this direction. Even fully austenitic steels are susceptible to stress corrosion. If impurities are present in a condenser during the starting-up or running-down stages then damage can take place. Especially dangerous are the presence of chlorine ions.

About two years ago there was in Germany an instance of damage caused through stress corrosion to a fully austenitic 16% Cr–13% Ni–Mo–V steel. In this case a leakage of soda lye, caused by the incorrect switching on of the plant, resulted in stress corrosion which developed within a period of 25 minutes. Chlorine ions were present in the soda lye.

The only possibility of preventing damage from stress corrosion is to plan the plant accordingly and to ensure that it is properly attended once it has been put into production. Sometimes a stress-relieving treatment of the austenitic welds is possible.

Another important reason for the use of fully austenitic steels in plant working constantly at high temperatures is that such steels have a good resistance to sigma-phase embrittlement. If residual ferrite is present in the weld deposit, as is the case for example with 19/9 Cr–Ni steels, then there is a danger that after 5,000–30,000 hr running time the notch impact strength will fall to 1–2 mkg/sq.cm. Such a state of embrittlement rightly gives cause for anxiety.

Welding problems

For the purpose of welding these fully austenitic steels, electrodes are used that produce a fully stabilized weld deposit which is as similar as possible to that of the base metal. The creep resistance at least must be equal to that of the base metal. The change-over from 19/9 Cr–Ni type electrodes to fully austenitic stabilized electrodes of the 16% Cr–13% Ni–Nb type gave rise to many welding problems, particularly that of cracking of the weld joints.

There are of course fully austenitic filler materials that are not susceptible to cracking; for example, those based on 19% Cr–9% Ni–6% Mn alloys. These, however, could not be used because of their insufficient creep resistance properties. In addition to this their relatively high carbon content is not fixed by stabilizing elements.

In submerged-arc welding of these materials the austenitic base metal is not preheated, and under certain circumstances a cooling of the base metal may prove to be advantageous. The current used for welding should not be much more than 500 amp with a voltage of 28–30 V. If UM 80 or UM 90 powders are used, allowances should be made for Cr losses due to burn-out. These losses are in the region of 15% of the total. If UM 88 powder is used the Cr pick-up is approximately 2·5%. If the filler wire contains Ta and Nb then a loss through burn-out amounting to approx. 50% of these elements must be allowed for.

A retention of the alloying elements is obtained when welding austenitic steels by means of the Mig process. If a gas envelope of argon gas containing 1%

Table VI

Composition of austenitic high-temperature constructional steels

Type of Steel	*Analysis, %*						*Other Additions*
	C	*Si*	*Mn*	*Cr*	*Ni*	*Mo*	
16%Cr13%NiNb	<0·10	0·30	1·0–1·4	16·0	13·0	—	10xC%Ta/Nb
16%Cr13%NiMoVNb	<0·10	0·30	1·0–1·4	16·0	13·0	1·3	0·75V; 10xC% Ta/Nb
16%Cr16%NiMoNb	<0·10	0·30	1·0–1·4	16·0	16·0	1·8	10xC%Ta/Nb
13%Cr13%Ni10%CoMoWNb	0·40	1·50	1·0–1·4	14·0	12·0	2·0	2·5W; 10·0Co; 3·0Ta/Nb
20%Cr20%Ni20%CoMoWNb	0·40	0·55	1·20	20·0	20·0	4·0	4·0W; 20Co; 4·0Ta/Nb

oxygen is used then the Cr burn-out amounts to approx. 1%, whereas the burn-out losses of Ta and Nb are reduced to less than 10%. Materials of the 19/9 and 19/10/2 types are usually welded by the Mig process.

In comparison with the Mig process the welding of austenitic steels by the submerged-arc process is less efficient and the quality of the welds is somewhat inferior. For this reason the Mig process is mainly used in Germany for plant production, and good results have been obtained.

Although experiences in the welding of 19/9 and 19/10/2 types of steel have proved to be successful, the results obtained in the field of fully austenitic materials such as 16/13 or 16/13 Mo V have been far less satisfactory. Neither the submerged-arc nor the Mig process has as yet produced satisfactory results and microscopic cracks and fibrous fractures are constantly developing.

Forms of cracking

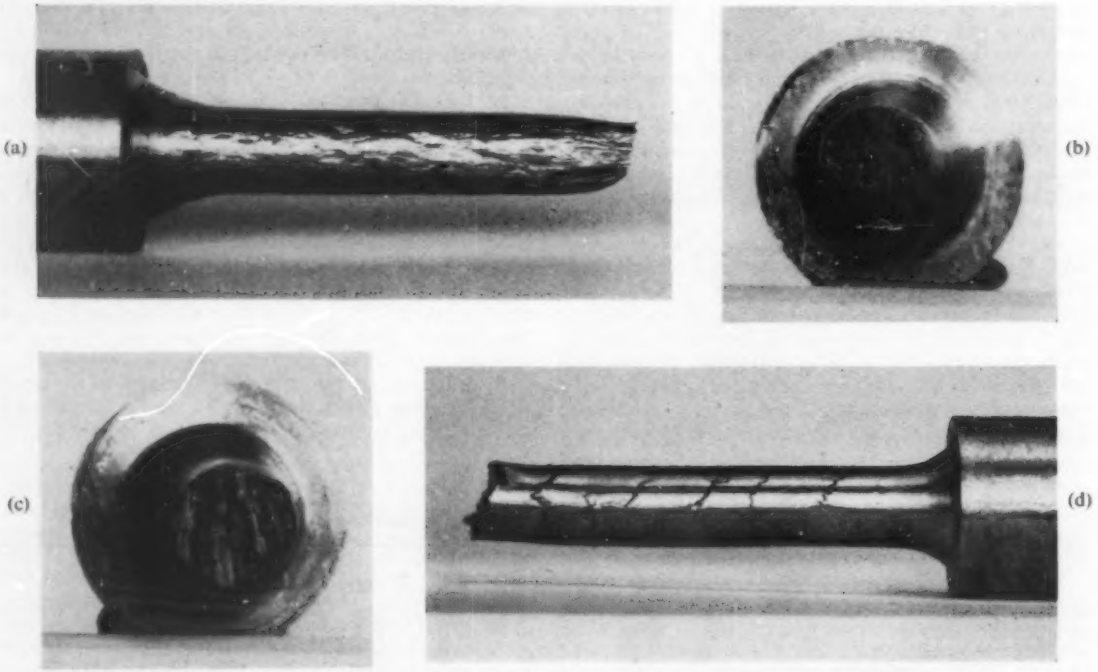
Before dealing with the question of crack formation and of the use of suitable electrodes and welding methods, the various types of cracks will be described.

The most pronounced faults are the heat cracks that appear on the surface during the process of welding. They are distributed irregularly over the weld seam and are usually not longer than 10–15 mm. These crack formations are not straight but are usually 'hook' shaped. The insides of the crack are temper-coloured blue, which shows that the cracks form shortly after welding. Under load, these cracks can continue to extend into the sub-layers of the weld.

Of a much more dangerous nature are the macroscopic crack formations which are situated under the surface of the weld and which cannot be seen (Fig. 9). They usually form during the welding of extra thick sections, and they also appear in the form of hook-cracks if a tensile or bend test piece is made from the weld deposit (Fig. 10).

9—Macroscopic intercrystalline cracks in welded joint of 16% Cr –13% Ni–Nb steel. (Section through weld centre)

The inside surface of the fracture area is not discoloured because air has not been able to penetrate into it. The appearance of the fracture of the weld



10—Types of fracture in tensile specimens of all-weld-metal deposit of 16% Cr–13% Ni–Nb: (a) *Normal;* (b) *deformed;* (c) *fibrous;* (d) *hook-shaped cracks*

11—*Radial crack in fully austenitic weld joint*

deposit differs from that of a normal deformation fracture (Fig. 10*a*, *b*) by the fact that it is of a fibrous nature.

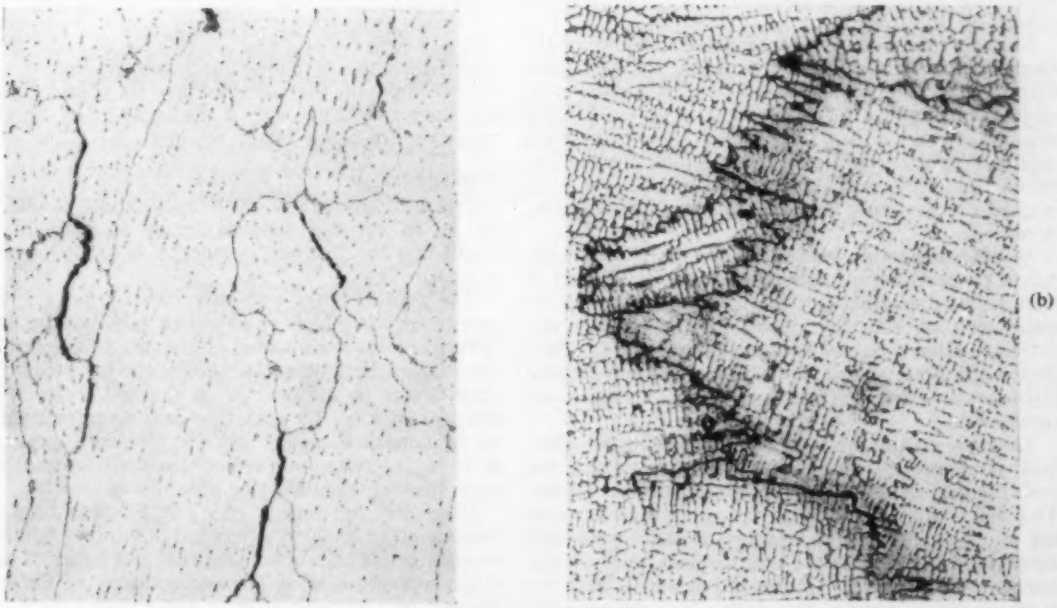
In addition to these faults there are end crater cracks which form during the welding of root welds of thick sections. They are usually easily recognizable and it is essential that they should be ground out. They may also be found in the first three passes covering the root weld. This crack formation in the end crater is probably connected in some way with the so-called 'star crack' formation (Fig. 11).

If a crater crack is not ground out but only welded over, a star crack usually appears in the subsequent pass. If the surface of the weld is not machined these cracks are usually difficult to identify, but if the surface is only coarsely machined, by grinding for example, they become visible. The cracks usually radiate from a central point, and individual fissures have a length of up to 3 mm. Most of these faults come to light during X-ray or ultrasonic testing.

Apart from these types of cracking very dangerous micro-cracking often appears during welding (Fig. 12). The cracks are inter-crystalline in nature and do not show up when testing with X-ray or ultrasonic apparatus. Their length and distribution throughout the weld is variable. Micro-cracks are to be found, not only in the weld deposit itself, but also in the transition zone (Fig. 13). Micro-cracks in the base metal itself usually appear when castings made from the aforementioned austenitic alloys are welded.

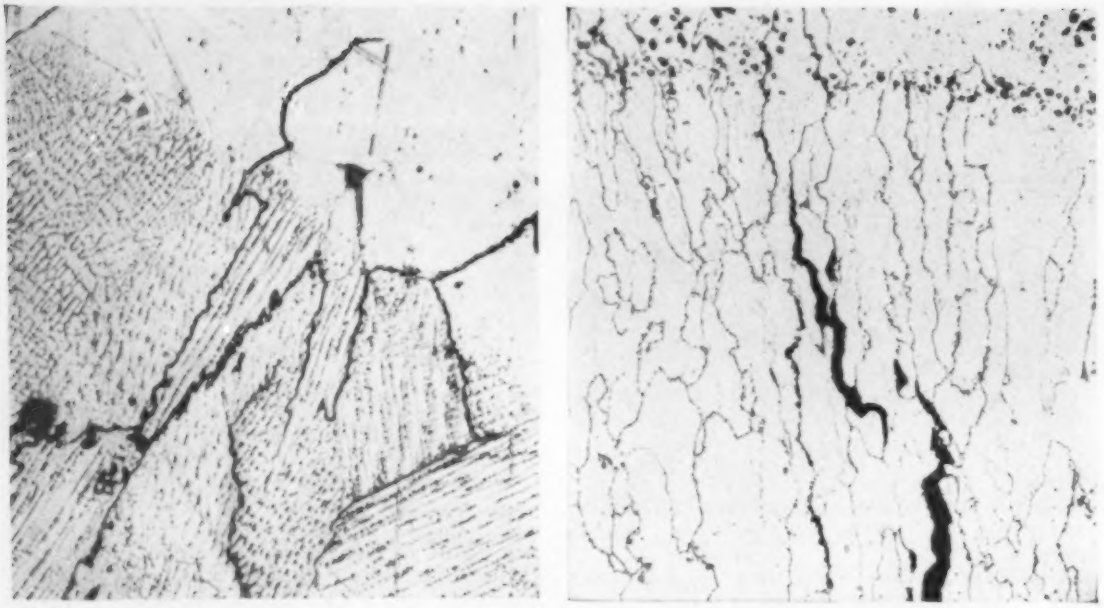
It must be assumed that all of the crack formations described have the same basic origin; they are all inter-crystalline in nature. Extensive research into their origin has shown a direct connection between the degree of de-oxidation of the weld deposit and its susceptibility to cracking. Metallographic studies have shown that the grain-boundary substance plays an important part in this connection. The nature and distribution of this substance is dependent upon its viscosity, *i.e.*, upon its melting point. This in turn is dependent upon chemical composition which is directly related to the de-oxidation measures adopted.[6]

This state of affairs is further influenced no doubt by the size of the primary crystals of the deposited materials. In this respect the coarse-grain type is far more susceptible to cracking because, by virtue of the reduction in grain boundary area, the degree of distribution of the grain-boundary substance is far less favourable than is the case with fine-grained structures.



(a) (b)

12—*Microscopic cracks in fully austenitic weld deposits:* (a) *Metal-arc, 40 mm wall thickness;* (b) *argonarc, 6 mm wall thickness*



(a) (b)

13—*Larger cracks in transition zone of weld joints in 16% Cr–13% Ni–Nb tube:* (a) *Metal-arc, 40 mm wall thickness;* (b) *argonarc, 6 mm wall thickness*

Filler materials

Research has shown that the quality of the electrodes and welding wires used is also very dependent on their metallurgical character, *i.e.*, on the technique of manufacture of the core wire. The practice of melting austenitic core wire heats in electric arc furnaces has, however, shown that the necessary metallurgical technique is extremely difficult to apply in practice in view of the manifold influences involved in the melting procedure.

Manufacturers of welding electrodes and wires are therefore forced to select heats suitable for the manufacture of welding rods of this type from a number of melts. To be able to do this the appropriate testing must be carried out, and it is essential that the methods used are selective and capable of differentiating between material suitable for the manufacture of electrode cores and material suitable for argonarc wire.

In estimating the suitability of heats, the mechanical properties (especially the elongation values) as well as the appearance of the fracture itself must be taken into account. Test pieces for this purpose are extracted from a bar of weld metal that has not been previously heat treated. In addition, metallographic tests are made and crack tests on critical materials are carried out.

Through making appropriate changes in the coatings of electrodes it is also possible to reduce the susceptibility of the weld deposit to micro-cracking. This aim is achieved through the application of coating methods directed at bringing about a post-weld de-oxidation of the molten weld deposit, through the introduction of suitable de-oxidation agents into the coating. Such agents are iron, ferro-manganese, manganese metal, as well as tantalum, niobium and zirconium alloys. Under certain circumstances it is also possible to reduce the grain size of the weld deposit by making such additions. In this connection attention must be drawn to the fact that positive results can be achieved only with basic lime coatings. Through the addition of rutile to the coating the results obtained from the fully austenitic core wires mentioned are adversely affected.

It must be emphasized that the austenitic filler metals mentioned and their weld deposits cannot be compared with the exceptionally tough welds of the 19% Cr–9% Ni or 19% Cr–10%Ni–2% Mo types. Even when the best filler materials are used a weld deposit free of micro-cracks can be obtained with reasonable certainty only if the appropriate countermeasures are taken during welding.

Welding technique

The weld groove form to be used should be selected so as to provide the maximum accessibility for depositing the root pass; generally, U-shaped grooves are used.

The welding of the end crater can lead to complications even when high quality filler materials are used. When welding with coated electrodes a little skill on the part of the welder can prevent the formation of a deep crater if, at the end of the weld, the arc is directed back on the weld, thus causing extra material to be deposited at the end. Despite such measures, however, an occasional crater crack will appear, and such cracks must always be ground out.

Originally, the making of a straight weld bead was considered to be the best method of welding but more recently it has been concluded that it is better to use a slight weaving action. The susceptibility of the weld deposit to micro-cracking is not thereby increased, and the formation of slag inclusions is prevented, for the bead is no longer extremely convex, but fills out

the surface of the weld. At the same time the subsequent work of grinding is reduced considerably. With thick sections, however, it must be ensured that no widely woven bead is laid in the middle and upper layers of the weld. The width of the weave should not exceed 3 times the diameter of the electrode. It will therefore often be necessary to fill the upper layer of the weld by using two woven beads deposited side by side.

Electrodes more than 4·125 mm dia. should not be used, for the thermal conductivity of austenitic steel is far less than that of plain carbon steel. Of equal importance in the welding of such steels is that the arc length should be kept short. When welding thick-walled tubes and pipes the welding should be carried out so as to enable the arc to be directed against the weld itself; *i.e.*, the electrode should be held at a steep angle so as to prevent the deposition of a thick layer, which would automatically lead to local overheating.

Experience has shown that thin sections of up to about 6·25 mm should be welded by the argonarc process. Where thick sections have to be welded, the root weld should also be welded by this process. When welding root passes with electrodes, except when welding in the horizontal position using a backing, the holding of a short arc and the creation of 100% slag coverage is extremely difficult.

Heat treatment

Of great importance in the case of welding these austenitic steels is the problem of preheating. Experience has shown that the high preheating temperatures of 500°–550°C., which were originally thought to be ideal for eliminating welding stresses, are in fact too high. The high preheating temperature together with the heat introduced during welding can lead to a localized overheating and the formation of cracks. When welding the root pass it is best to preheat the base metal to a temperature of 100°–150°C. No further preheating is then necessary, but care should be taken during welding that the temperature does not exceed 200°C.

Austenitic steels do not usually require a subsequent heat treatment, but in sections where a stress build-up may occur (for example, where the cross-sections are large or where there is a concentration of weld seams) it may be advantageous to carry out stress-relieving heat treatment. In view of the mechanical properties of austenitic steels at elevated temperatures such stress-relieving must be carried out at a temperature of 850°–900°C.

Special attention should be paid to the welding methods described, especially where complicated austenitic steels such as 16/13 Cr–Ni–Mo–Nb, 16/13 Cr–Ni–Mo–V–N–Nb, and 16/13 Cr–Ni–Mo–Nb have to be welded. Special electrodes are available for such purposes, but our company has adopted a policy whereby the materials mentioned are welded with electrodes which deposit a stabilized weld containing 15–16% Cr, 12–13% Ni, and 5–6% Co. The weld deposit has good mechanical properties, with an elongation of 30–40%, and it does not embrittle during long periods at working temperatures 600°–700°C. Because of its high Co content the weld deposit of the alloy 16/13 Cr–Ni–Co gives somewhat better creep values than the steels already mentioned (Fig. 14).

High Nickel Alloys

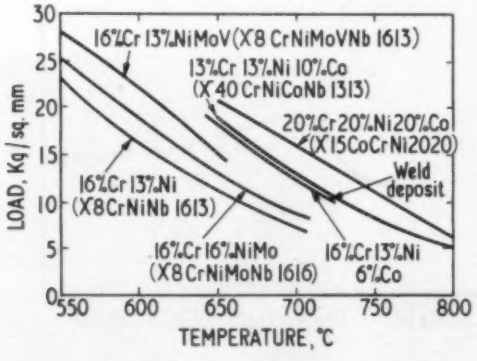
Steel containing 13% Cr–12% Ni–10% Co introduces the special steels for service at very high temperatures. This steel has been welded successfully with the 16/13 Co electrodes already mentioned. The steel with 20% Cr–20% Ni–20% Co plus Mo and W represents the present limit of weldability. Tests carried out on all-weld-metal specimens made with electrodes of a similar type produced the following results:

Yield point	47·5 kg/sq.cm (30 tons/sq.in.)
Rupture strength	61·0 kg/sq.mm (39 tons/sq. in.)
Elongation	12%

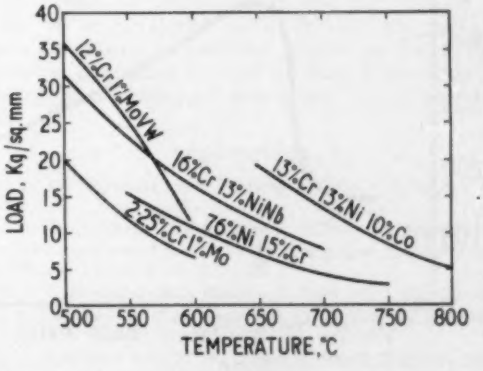
No heat treatment was carried out after welding.

Welded joints of 16/13 Cr–Ni–Mo–V material with 20% Co steel were not in every case perfect, although the results were satisfactory. Research in this direction continues.

Ever since austenitic steels have been used for steam pressure vessel construction it has been necessary for them to be joined to ferritic high-temperature service steels. In addition, austenitic steels of various types have to be welded together. The most simple means of doing this is through the application of welding.



14—*Creep resistance of high-temperature and ultra-high-temperature materials. Rupture after 10⁴ hr*



15—*Creep resistance of high-temperature and ultra-high-temperature materials. Rupture after 10⁴ hr*

Originally 25% Cr–20% Ni or 19%Cr–9% Ni electrodes were used, but other possible solutions became apparent when some of the high-Ni filler materials appeared on the market. The alloys mostly used contain 60–80% Ni in addition to 13–17% Cr, 5–12% Fe and some Mo as well as Nb. Sometimes the Cr values are lower and the Mo values correspondingly vary by 20%. The best known filler materials manufactured from Ni alloys are Inco-weld A, Inconel, and Hasteloy W. In Germany development in this field has only just commenced.

The creep strengths of the nickel alloys are lower than that of fully stabilized austenite (Fig. 15). If filler materials with high Ni contents are used there is the advantage that diffusion of iron, nickel or chromium from the base metal to the weld does not create an alloy in the weld that is susceptible to cracking. Even under load at elevated temperatures for long periods there is no sign of a sigma-phase developing.

For the welding of these nickel alloys no preheating is normally necessary, but it can be applied if the materials have a tendency to harden in the heat-affected zone (Fig. 16). For example, the hardness in the transition zone of a 12% Cr steel and an Inco-weld A weld deposit is so high that, to eliminate stress concentrations, heat treatment after welding is absolutely necessary. The curve in Fig. 16*b* shows the reduction in hardness that results from stress-relieving. It is immaterial whether a short heat treatment is carried out at a higher temperature or whether a prolonged treatment at a lower temperature is used. The macrographs in Fig. 16 show to scale the sections of the weld joint on which hardness tests were made.

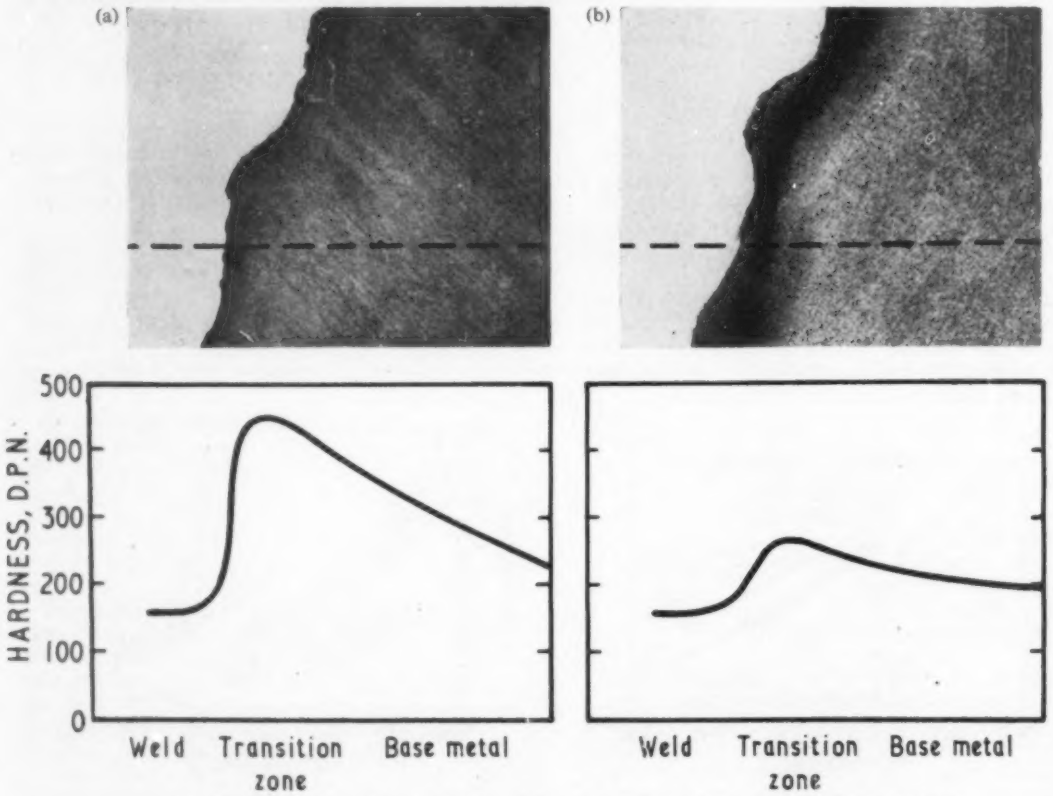
Similar conditions arise when 2·25% Cr steels are welded with Inco-weld A rods.

Welding with Nickel Electrodes

This final section includes some of the results that have been obtained in the field of pipe welding in which Inconel electrodes were used to weld high-temperature service ferritic steels to austenitic material.

In the first case 16/13 Mo–V–Nb material was welded to a 12% Cr steel. A U-shaped groove with a 12° flank angle was first prepared. For the root a 3 mm thick V weld was used. The preheating temperature of 400°C. was in keeping with the temperature laid down for welding 12% Cr steels. Inconel electrodes with a diameter of 3·25 mm were used. During welding the straight bead technique was used, minor cracks in the end crater being carefully ground out.

In the second case 16/13 Mo–V–Nb material was welded to a 1% Cr steel, the edges being U-shaped grooves with a 30° open angle on the ferrite side. The root was 1·5 mm thick and was welded as a butt seam. The root pass was made with 3·25 mm dia.



16—*Grain structure and hardness of transition zone of Inco-weld A and 12% Cr–1% Mo–V–W:* (a) *As-welded;* (b) *after tempering for 100 hr at 700°C.*

Table VII

Mechanical properties of joints welded with Inconel[7]

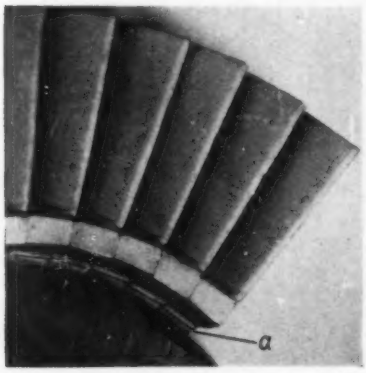
Weld Joint	*16%Cr 13%Ni Mo V Nb Inconel 12%Cr 1%Mo V W*	*16%Cr 13%Ni Mo V Nb Inconel 1%Cr 0·5%Mo*
Yield Point, kg/sq.mm	33·1	36·5
Tensile Strength, kg/sq.mm	63·3	50·4
Elongation, %	19·6	14·0
Reduction in area, %	61·6	79·8
Notch Impact (root)	8·0	7·3
Strength, mkg/sq. cm (top layer)	11·0	5·4

Inconel electrodes and the ferrite side was also clad to a thickness of 3 mm with the same electrodes. The rest of the weld was filled with 16/13 Mo–V–Nb electrodes. For the coating of the ferrite side a preheating temperature of about 300°C. was used. Subsequent heat treatment was carried out at 750°C. on the construction site by means of ring burners.

X-ray and metallographic testing on both welds and joints showed no faults. The mechanical properties obtained are given in Table VII.[7] Both welds had excellent tensile properties. For the purposes of plant construction it is certainly advantageous to weld the whole joint with Inconel rather than to use only a thin coating. In this way differences in hardness and coefficients of expansion can be bridged over to a greater degree.

These results demonstrate the possibilities of welding high-temperature service ferritic steels to austenitic steels using filler materials with a high Ni content having suitable coefficients of expansion. It is therefore hoped that in this way it will be possible to weld together large sections on the construction site itself.

Far greater difficulties are met with in the construction of steam and gas turbines than those experienced in the field of steam pressure vessel and valve construction. In the former instance the weld is also subjected to dynamic forces so that the joints are especially critical. The most difficult problem is that of welding turbine blades on turbine rotors and of welding such blades to the walls of turbine casings (*see* Fig. 17). Austenitic materials are usually used for welding work carried out on such rotors or housings. Sometimes however (if the working temperature is less than 600°C.) ferritic material is also used.



17—*Locating turbine blades before welding:* (a) *weld groove*

When turbine blades are set up on the rotor it is impossible to avoid minute gaps between the roots of the individual blades. These gaps are then interrupted by the weld seam and give rise to extremely high stress concentrations. It is therefore very necessary that the electrodes used for making these joints should not be susceptible to cracking. A very critical test used for determining the suitability of such electrodes is the Brown Boveri crack test. In this test a straight weld is drawn across a bundle of steel plates consisting of either eight plates of the same material or the same number of alternating ferritic and austenitic plates which have been bolted together. If no cracks, originating from the gaps between the individual plates, appear in the weld the electrode is deemed to be suitable for the welding of turbines.

For the welding of austenitic to ferritic materials for use at temperatures up to about 570°C., extremely crack-resistant electrodes of the type 19% Cr–9% Ni–3·5% Mo are available. Their efficiency has been proved in the manufacture of a long series of waste-gas turbines. These electrodes cannot however be used for temperature ranges above 570°C. because the ferrite content of the weld deposit then causes a drop in notch impact strength values. After a run of 100,000 hr at 600°C. the notch impact strength drops to about 2 mkg/sq.cm. After 30,000 hr at 650°C. it is about 1·7 mkg/sq.cm, and after 100,000 hr it is as low as 1 mkg/sq.cm.

In the temperature range 600°–700°C. and at 750°C. only extremely high-temperature service alloys of the type 16% Cr–16%Ni–2% Mo and also the types 14%Cr–12% Ni–10% Co as well as 20% Cr–20% Ni–20% Co can be used. The welding of turbine blades of the materials mentioned has not yet been carried out successfully so as to eliminate cracks, and the policy of anchoring the blades mechanically to the rotor is still preferred.

For less critical applications, such as the manufacture of hollow shafts and joints on rotor discs made from 14% Cr–12% Ni–10% Co types of steel, the 16% Cr–13% Ni–6% Co electrodes already mentioned are used. The more ductile weld deposit of the 16/13 Co electrode is suitable for joints on the steel already mentioned, for its creep properties are very similar to those of the 14/12/10 steels. Such welds are technically possible and have been tested in practice.

The results of investigations into the reaction of welds at temperatures above 650°C. are not yet available. There is however reason to hope that austenitic electrodes for use at these high temperatures may be produced which will be of practical value.

REFERENCES

1. C. L. M. COTTRELL: *Brit. Welding J.*, 1954, vol. 1, pp. 177–186.
2. C. L. M. COTTRELL: *Brit. Welding J.*, 1954, vol. 1, pp. 167–176.
3. E. KAUHAUSEN and S. SADOWSKI: *Schweissen und Schneiden*, 1959, vol. 11, no. 4, pp. 115–120.
4. M. C. T. BYSTRAM: *Brit. Welding J.*, 1958, vol. 5, pp. 475–480.
5. E. KAUHAUSEN and P. KAESMACHER: *Schweissen und Schneiden*, 1957, vol. 9, no. 9, pp. 114–119.
6. E. KAUHAUSEN and H. A. VOGELS: *Metal Progress*, 1955, vol. 67, no. 1, pp. 129–136.
7. J. CLASS: "State of Development of Permanent Ferritic-Austenitic Joints". Report of VGB, 1959, pp. 181–207.

Hot Pressure Welding of Titanium

Values of deformation and pressure required to give welding between room temperature and 900°C. have been obtained. Pressure butt welding of titanium bar was carried out between 500°C. and 900°C. and the tensile results are reported together with the microscopical changes occurring at the interface. A heat treatment, of 30 minutes at 950°C., increased the tensile properties of any weld to those of the parent material.

By C. F. Wilford and R. F. Tylecote, M.A., PH.D.

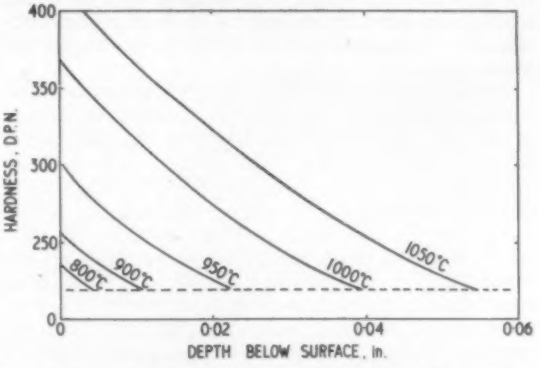
PRESSURE welding is the process by which two pieces of metal are joined when a pressure is applied to them, usually in a direction normal to the interface of the two pieces; no melting occurs at any stage of the operation. The quality of the weld depends primarily on the amount of upset achieved and the temperature of welding. Tylecote[1] has already discussed procedures for pressure welding on an industrial scale.

Titanium has already been pressure welded successfully: Voldrich[2] reported that oxy-acetylene gas heating of the pieces to 1200°C. in less than one minute was used, the short time at high temperature ensuring that gas pick-up and its associated surface embrittlement did not occur appreciably. Hughes[3] prevented gas pick-up by using cold pressure welding, deformations in the region of 80% being required for high strength joints. This value is regarded as the maximum allowable on an industrial scale, and it seemed appropriate to investigate welding conditions between the foregoing limits of temperature and deformation.

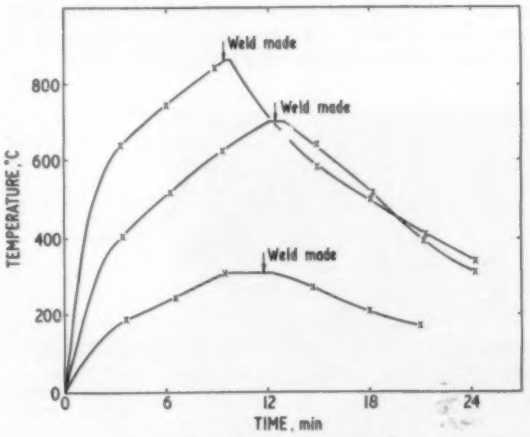
Experimental Procedure

When titanium is heated above about 700°C. in air, oxygen and nitrogen enter the metal to form an interstitial solid solution which is much harder than the pure metal. However, the depth of this hardened and consequently embrittled surface layer is not great for temperatures below 1000°C. and for times up to 1 hr, as is shown in Fig. 1 (from a paper by Cook[4]). It was decided, therefore, to weld at temperatures below 1000°C. and also to use a fairly rapid rate of heating to reduce gas pick-up.

As titanium has a low thermal conductivity, it is necessary to hold the specimens to be welded at a steady temperature while temperature gradients across the diameter of the two pieces are reduced, if a constant bond-strength across the whole of the interface is to be achieved. From these considerations it was decided to surround the titanium with a stainless-steel heating coil carrying a high current at low voltage. The heat generated in the coil was varied by means of



1—*Hardness of titanium after heating for one hour in air (after Cook[4])*

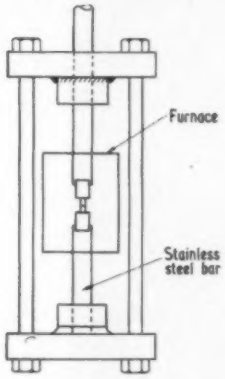


2—*Typical time–temperature cycles*

Manuscript received 22nd December, 1959.
Mr. Wilford is at the U.K.A.E.A., Springfields. Dr. Tylecote is in the Department of Metallurgy, University of Durham, King's College, Newcastle-upon-Tyne.

a variable resistance in the primary transformer circuit, and actual heating currents of between 100 and 200 amp at 15 V could be obtained. Typical heating rates are shown in Fig. 2.

The welding rig (Fig. 3) was designed so that alloy-steel indenting tools (for pressure-welding sheet) or steel holders for titanium bar, could be fitted into the stainless-steel bars, through which the pressure was

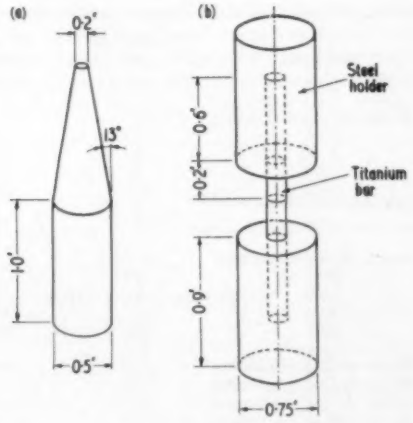


3—*Apparatus used for welding*

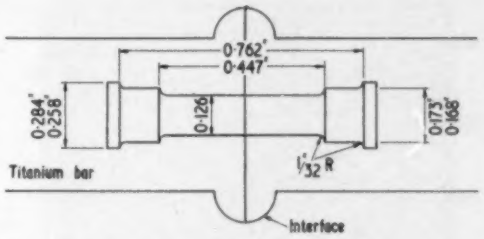
applied from a hydraulic press. The welding temperature was taken as the value recorded by a thermocouple touching the titanium specimens at their interface. The dimensions of the indenting tools and the titanium bars in their expendable mild steel holders are shown in Fig. 4, the steel holders acting to restrain deformation over the most part of the bars and to allow it to occur only in the region of the interface.

The material used for sheet welding was commercial purity titanium, with a hardness of 200 D.P.N., in the form of strip 1 in. wide and 0·050 in. thick. The titanium bar had a hardness of 170 D.P.N. and was $\frac{3}{8}$ in. dia.

A standard pre-weld treatment of de-greasing and scratch-brushing was used followed immediately by welding. A stress of 20 tons/sq.in. on the welding tools or on the interface of the bars was applied to reduce gas



4—*Dimensions of the tools used:* (a) *Lap welding of sheet;* (b) *butt welding of bar specimens*



5—*Dimensions of the tensile specimen and its relation to the weld specimen*

pick-up at the interface, this stress being gradually released as the titanium heated up to the welding temperature, where the welding force was applied and retained for 10 secs.

The dimensions of the test piece machined from the bar welds and its position in relation to the weld are shown in Fig. 5. The small size of test specimen meant that any contamination from superficial oxygen penetration would be removed before testing. In industrial practice such contamination would be confined to the upset material and could be removed if necessary.

Results and Discussion

The results obtained from the welding of sheet are illustrated in Figs. 6 and 7, where the curves show the minimum deformations and pressures at various temperatures required to give welding, the criterion of the just-welded value being that the weld survived a simple drop-test. The measured deformation in this case was the percentage reduction in thickness *i.e.*:

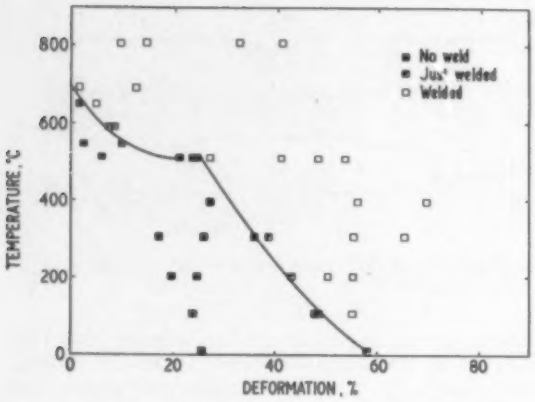
$$\frac{T-t}{T}\times 100$$

where T is the total thickness before, and t is the thickness after welding.

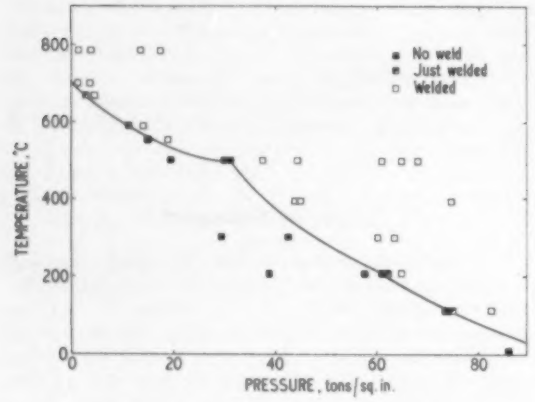
Microsections of several welds were etched in a solution containing one part HNO_3 and one part HF and two parts glycerol, and examination of these showed that the sudden change in slope in the curves at 500°C. was due to the commencement of recrystallization in the weld region at this temperature. The extent of deformation to give welding was considerably reduced once recrystallization had begun (and the associated pressure to give this reduced deformation was, of course, also less). This observation is not surprising, for recrystallization is merely the outward appearance of increased atomic movement and it is this increase which makes welding easier. The importance of diffusion has already been discussed by Kinzel.[5]

The value of 57% minimum deformation to weld titanium at room temperature is comparable with 60% needed to weld aluminium, although the pressure to give this deformation is much higher for titanium. At 700°C., the deformation required is virtually zero, it now being only necessary to apply sufficient pressure to prevent gas pick-up at the interface during the welding cycle.

Table I shows the conditions during the welding of titanium bar and the tensile results obtained from the



6—*Welding deformation/temperature curve for sheet*



7—*Pressure/temperature curve for sheet*

welded specimens. In this case the deformation is the percentage increase of interfacial area *i.e.*:

$$\frac{A-a}{A} \times 100 = \frac{D^2-d^2}{D^2} \times 100$$

where A is the area after welding
a is the area before welding
D is the diameter after welding
and d is the diameter before welding.

Welds made at temperatures below 500°C. show a cold-worked region in which was found what appeared to be lens-shaped voids and discontinuities. An example of this is shown in Fig. 8. At temperatures above 500°C. recrystallization occurs to a varying extent; for example, a weld made at 785°C. with 15%

8—*Weld made at 495°C. with 53% deformation* ×400

Table I

Conditions for pressure butt welding of titanium and tensile test results of welded bar

	Temp. of Welding, °C.	*Pressure, tons/sq.in.*	*Deformation, %*	*U.T.S., tons/sq.in.*	*Elongation ($4\sqrt{A}$), %*	*Red. in Area, %*
1	Titanium 'as-received'			29·6	36	70
2	900	1·4	23	Broke during machining	—	—
3	900	1·4	37	29·4	1	2
4	900	1·4	41	27·6	2	3
5	900	1·4	55	30·5	3	2
6	900	1·4	63	31·3	32	55
7	800	15·4	66	32·6	38	70
8	680	19·0	48	Broke during machining	—	—
9	680	19·0	55	29·7	2	3
10	680	19·0	60	28·9	3	6
11	680	19·0	61	30·1	39	75
12	680	19·0	65	29·4	32	75
13	500	45·3	39	Broke during machining	—	—
14	500	45·3	44	Broke during machining	—	—
15	500	57·0	50	Broke during machining	—	—
16	500	61·5	53	Broke during machining	—	—
17	500	61·5	56	34·2	1	5

9—*Weld made at 900°C. with 44% deformation* ×600

10—*Weld made at 500°C. and heat-treated at 950°C. for 30 min* ×500

deformation shows virtually complete recrystallization.

The occurrence of recrystallization is dependent upon welding temperature, welding deformation, and rate of cooling from the temperature of welding. It is therefore, to some extent, a function of the apparatus in use.

Welds made at 900°C. show a martensitic structure in the region of the interface (Fig. 9), the intensity of this effect being greatest around the discontinuities. The occurrence of this structure is probably explained by the conclusion arrived at by Vaidyanath, Nicholas, and Milner[6] that these primary discontinuities indicate the position of the oxygen absorbed into the original scratch-brushed layer. During the welding cycle much of the absorbed oxygen and nitrogen begins to diffuse into the parent metal and gives rise to the martensitic structure on cooling. This effect would be noticed only in high-temperature welds with a short heating cycle, although the diffusion of oxygen and nitrogen from the scratch-brushed layer must occur to some extent at lower temperatures.

As Table I shows, there is a critical deformation for welding (at any given time and temperature), above which the weld is ductile when tested, and below which it is brittle. For example, a specimen welded with 60% deformation at 680°C. gives 3% elongation on testing, and with 61% deformation gives 39% elongation. Microsections of welds at 58%, 60%, and 62% deformation at 680°C. were therefore examined:

58% deformation shows extensive discontinuities and only a few grains have grown across the interface.
60% deformation shows several discontinuities and fairly widespread grain growth across the interface.
62% deformation shows almost complete trans-interfacial grain growth.

Heat-treatment

It has already been noted that welding at 900°C. causes the oxygen and nitrogen absorbed and chemically combined with the titanium of the scratch-brushed

Table II

Welding conditions and tensile results after heat-treatment at 950°C. for 30 min

	Temp. of Welding, °C.	*Pressure, tons/sq.in.*	*Deformation, %*	*U.T.S., tons/sq.in.*	*Elongation ($4\sqrt{A}$), %*	*Red. in Area, %*
1	Parent Metal (heat-treated)			28·8	34	65
2	900	1·4	22	27·7	32	55
3	800	2·3	8	29·6	33	55
4	680	19·0	50	28·7	38	65
5	680*	19·0	52	30·9	38	70
6	500	61·5	44	29·3	38	65
7	500	61·5	46	30·1	40	65

* Water quenched from 950°C.—others were air cooled

Table III

Conditions of welding and results of impact tests

	Temp. of Welding, °C.	*Pressure, tons/sq.in.*	*Deformation, %*	*Heat Treatment*	*Impact Strength, ft-lb*	*Fracture*
1	Material 'as-received'			None	21	Very smooth
2	Material 'as-received'			30 min—950°C.	38	Rough
3	900	1·4	57	None	8	Slightly rough
4	900	1·4	63	None	15	Slightly rough
5	900	1·4	48	30 min—950°C.	31	Very rough
6	900	1·4	55	30 min—950°C.	38	Very rough

layer to diffuse a short way into the parent metal, causing marked hardening as is implied in Fig. 1. A post-weld heat-treatment of, for example, 30 min at 950°C. should reduce the oxygen and nitrogen concentration in the interfacial area and improve the ductility of the weld. The results shown in Table II suggest that such a process is operating. The ductile fracture after heat-treating the weld formed at 800°C. with only 8% deformation, is particularly notable. Before heat-treatment this weld would have been so weak as to have broken during machining to test-piece size.

Microstructural changes during heat-treatment

The actual changes at the interface during heat-treatment depend upon whether or not recrystallization occurred during welding.

Figure 10 is a typical example of the interface of a weld made at 500°C. with 39% deformation and then heat-treated at 950°C. for 30 min. The discontinuities that were originally lens-shaped are now spherical.

Heat-treatment of any weld at 950°C. for 30 min results in widespread growth of grains across the original interface. Heat-treatment of a weld formed at 500°C. and below gives spherical voids at the interface, which have resulted from the globularization of the original lens-shaped voids. Welds formed below the α–β transformation temperature at 880°C. can still retain fine discontinuities after heat-treatment, although these were not observed in welds formed at 900°C.

Impact tests

Table III shows the conditions of welding and the results of Hounsfield balanced impact tests on some as-welded and heat-treated specimens.

A comparison of results, given in Tables I and III, shows that even a ductile weld in the "as-welded" condition (Table III, specimen 4) does not give the impact strength of the parent metal. The heat-treatment markedly increases the impact resistance of a non-ductile weld (Table III, specimen 5); but heat-treating a slightly better weld, *i.e.*, one made with higher deformation (Table III, specimen 6), results in an even higher impact resistance, now equal to the parent metal after the same heat-treatment. The results thus indicate that the impact test is more sensitive to weld interface properties than is the tensile test.

Conclusions

(1) The minimum deformation required to weld commercial purity titanium at room temperature is 57%, requiring a pressure of the order of 100 tons/sq.in.

(2) As the temperature of welding rises above 500°C. the minimum deformation becomes very small. At 700°C. the required pressure is merely that necessary to prevent gas pick-up at the interface during the welding cycle.

(3) Greater ductility and improved impact strength can be obtained by post-heating welds for 30 min at 950°C.

(4) Notched-bar impact tests are more sensitive to weld interface properties than the normal tensile test.

Acknowledgments

The authors wish to express their thanks to I.C.I. Metals Ltd., Witton, Birmingham, for the supply of titanium.

REFERENCES

1. R. F. Tylecote: *Brit. Welding J.*, 1957, vol. 4, pp. 113–120.
2. C. B. Voldrich: *Welding J.*, 1953, vol. 32, pp. 497–515.
3. J. E. Hughes: *Sheet Met. Ind.*, 1954, vol. 31, pp. 52, 54 and 60.
4. M. Cook: *J. Inst. Metals*, 1953, vol. 82, p. 3.
5. A. Kinzel: *Welding J.*, 1944, vol. 112, p. 4.
6. L. R. Vaidyanath, M. G. Nicholas and D. R. Milner: *Brit. Welding J.*, 1959, vol. 6, pp. 13–28.

NEWS
and Announcements

News of the Institute and Branches
B.W.R.A. · Other Societies ·
and Industry

INSTITUTE ACTIVITIES

ELECTION OF MEMBERS

The following elections were made at the Council meeting of 14th July 1960:

Member

F. Howarth (Bognor Regis)

Companions

J. Blackwood (Chertsey); E. McDonald (Sandakan, British North Borneo)

Graduate

O. Evans (Bishops Stortford)

Associates

A. V. Ananda Kumar (Coimbatore, India); E. K. Aiyela (Enugu, E. Nigeria)

Industrial Corporate Members

The Distillers Co. Ltd., Chemical Division (London)
Sir Robert McAlpine & Sons Ltd. (London)

MEETINGS

Welding Standardization

The first of the annual conferences on welding standardization will be held at the Institute on 7th December 1960.

The theme will be the role of welding standardization in production and export, and the two principal subjects for discussion will be carbon and low-alloy steel specifications and welded structures.

Christmas Lecture to Young People

The Annual Christmas Lecture to Young People will be given on Thursday, 5th January 1961, by Professor J. G. Ball of Imperial College of Science and Technology.

The meeting will be held at the offices of the Institute, 54 Princes Gate, and will start at 11.0 a.m. Admission is by ticket only.

Publications

"*Comparison of Brittle Fracture Tests*" This important report of Commission IX, Sub-Commission A (IIW/IIS–18–59, ex doc. IX–214–58: IXA–12–58; IX–217–58) has been reproduced by the Institute, and is available at 5*s.* a copy.

Orders should be sent to the Secretary, Institute of Welding, 54 Princes Gate, London, S.W.7.

"*Welded Connexions for Pressure Vessels*"

The Institute has just published for the International Institute of Welding Document IIS/IIW–30–59 "*Recommended Welded Connexions for Pressure Vessels*". Copies are obtainable, price 4*s.* 6*d.* inclusive of postage, from the Secretary of the Institute.

SCHOOL OF WELDING TECHNOLOGY

The following courses in the School of Welding Technology of the Institute have been arranged for the first part of 1961:

16th–20th Jan., D.15/2—Brazing Technology and Design
30th–31st Jan., D.32—Design for Welding in Thermoplastics
13th–17th Feb., D.5/3—Non-Destructive Weld Examination
27th Feb.–3rd March, D.22—Welding of Atomic Energy Plant
13th–17th March, D.17/1—Advanced Course for Welding Engineers
27th–30th March, D.4/2—Resistance Welding Technology and Design

Courses provisionally arranged for the remainder of the year are as follows:

May: D.37—Advanced Ultrasonic Inspection
D.8/3—Welded Structures
D.33—CO_2 Arc Welding
Oct.: D.1/4—Welded Pressure Vessels
D.34—Welding Metallurgy
Nov.: D.13/3—Residual Stresses and Stress Relief
D.12/3—Practical Control of Distortion
D.28/1—Welding for Junior Management

NEWS OF MEMBERS

Mr. S. Rowden has taken up a post as Chief Metallurgist and Welding Engineer at Autodrome (Engineers) Ltd., Manchester.

Mr. E. H. S. van Someren has left the Research Department of Murex Welding Processes Ltd. to join the British Welding Research Association as a Principal Scientific Officer. He will be working on fundamental studies of the physics of the welding arc by optical observations.

Mr. D. J. W. Boag, Managing Director of Rockweld Ltd., was one of a party of British industrialists which left early in October to tour Western Australia.

Simon A. Greenberg, Industrial Consultant, and formerly Technical Secretary of the American Welding Society, has opened a new office in Flushing, New York. His objective is to serve industry in obtaining cost reductions, consistently uniform good quality, and profitable production.

Mr. N. L. G. Lingwood has relinquished his responsibilities as Distribution Director of British Oxygen Gases Ltd. He joined the Greenwich works of the British Oxygen Company as assistant engineer in the early 1920's.

Obituary

The Council regrets to announce the deaths of the following members:

Mr. Samuel Charles Ross, Managing Director of Richards and Ross Ltd., Wednesfield, Staffs. (Wolverhampton Branch, Member 1943).

Mr. C. E. D. Hodson, of Hodson Engineering, Broadstairs. (South London Branch, Assoc. Member, 1944.)

Mr. Basil Kenneth Hodge, Chief Engineer of C. & W. Walker Ltd. (Assoc. Member, 1956.)

Mr. Joseph N. Hammerson (Associate, 1957).

Mr. Carl Coulson-Smith, formerly Chief Chemist at British Oxygen Gases Ltd., Cricklewood (Member, 1929).

S. Sadowski

L. H. Toft

C. F. Wilford

CONTRIBUTORS TO THE JOURNAL

F. E. Asbury, B.Met., A.I.M., is a Research Metallurgist in the Materials Division of the Central Electricity Research Laboratories. He graduated from Sheffield University in 1951, and then joined the Metals Division of the Telegraph Construction and Maintenance Co. Ltd., at Greenwich and Crawley. He was engaged there on the development of special wrought alloys for the electronic and instrument industries.

Mr. Asbury took up his present position in 1957, and has since been investigating the properties of steels used in nuclear and conventional power stations, and in particular the effects of welding these steels. (*Paper in November issue.*)

P. Kaesmacher, Dipl.Ing., is Head of the Research Department for Welding of Böhler Bros. & Co. He studied metallurgy at the Technical College in Aachen and was awarded a Diploma. Before taking up his present appointment, he was for many years concerned with welding on the German State Railways.

Dr. E. Kauhausen is Research Director of Böhler Bros. & Co., Düsseldorf. He studied the metallurgy of iron and steel in Aachen and obtained a Diploma and his Doctor's degree there.

Dr. Kauhausen is still working in the field of iron and steel, giving particular attention to welding aspects.

B. Mitchell, A.Met., A.I.M., is in the Power Generation Branch of the Research and Development Department of the Central Electricity Generating Board. He was educated at Firth Park Grammar School and at Sheffield University.

Mr. Mitchell was first employed in the Firth Brown Research Laboratories until 1949 when he joined Hadfields Ltd. as a metallurgist in the Technical Liaison Department and specialized in high-alloy steels. He became a member of the Generation Operation Department of the C.E.G.B. in 1956 and subsequently took up his present appointment, in which he is mainly concerned with the development of materials for advanced steam cycles. (*Paper in November issue.*)

S. Sadowski, Chem.Ing., is a member of the Research Department of Böhler Bros. & Co. He studied chemical engineering in Berlin.

L. H. Toft, B.Sc., A.I.M., A.C.T. (Birm), is Section Head of the General Metallurgy Section in the Materials Division of the Central Electricity Research Laboratories. He was educated at Moseley Grammar School and at the College of Technology, Birmingham, and obtained a degree in Metallurgy of London University in 1945.

Until 1955, Mr. Toft was at the Research Laboratories of The Mond Nickel Co. Ltd., where he was engaged on work relating structure to the properties of ferritic and austenitic steels. Since taking up his present position, in 1955, he has been mainly concerned with the assessment of the performance of steels used in the construction of high-temperature steam generating plant. (*Paper in November issue.*)

C. F. Wilford was educated at Rutherford Grammar School, Newcastle upon Tyne and at King's College, University of Durham, where he spent his vacations at a branch of the English Steel Corporation and the Rocket Propulsion Department (at that time a part of the Royal Aircraft Establishment). During his final Honours Degree year, he worked on the pressure welding of titanium under the supervision of Dr. Tylecote.

He is now employed as a Scientific Officer in the Welding Department of Springfields Works, U.K.A.E.A., and has recently completed a programme on the welding of uranium. At present, he is investigating the arc welding of beryllium, and is particularly interested in welding the less common metals.

BRANCH NEWS

Manchester — Which Welding Process?

At the Manchester College of Science and Technology, on 5th October, Mr. B. K. Barber, M.A., lectured on "*The selection of welding processes*".

F. E. Asbury

P. Kesamacher

Dr. E. Kauhausen

B. Mitchell

As an introduction, he said that welding is but one of the many production processes involved in manufacture, which include casting, forging, presswork, machining, and so on. In addition there are also other methods of joining metals—brazing, riveting, bolting, and even the use of adhesives. All these are extremely valuable in their own spheres, so it is important to keep welding in its true perspective.

Where a welded unit is involved it is essential that the designer should have some knowledge of metallurgy, so that materials suitable for welding would be chosen. He must also be able to specify correct joint preparations, welding sequences, and testing procedures; all too often the drawing has vague expressions like 'fill with weld metal' or 'weld all round'. This implies that the welding operator is being asked to specify the length and sizes of welds, a task for which he is most assuredly not trained.

Mr. Barber explained that there were more than 30 welding processes from which to choose one that was suitable for a given task. Charts were distributed among the audience so that the processes could be referred to under the two main groups: Fusion welding, and pressure welding.

The factors to be considered in selecting the appropriate process were: (i) Material; (ii) shape, size, quantity, and quality of the required fabrication; (iii) production considerations, such as availability of equipment, operator skill, design staff, management enthusiasm; (iv) cost consideration; (v) cost of the finished product. The author went on to discuss these factors in detail.

In conclusion, and under the heading 'Who selects the process?' Mr. Barber remarked that everybody thinks that he knows something about welding, but unfortunately (or fortunately?) no one has all the answers. It is usual that all those concerned, the Chief Engineer, Chief Designer, Drawing, Planning and Method Study departments, Works and Shop Managers, Metallurgist, and Welding Engineer, want some say in the matter. So it was to be hoped that these problems are solved by mutual co-operation. The lecturer had heard of one poor welding engineer who had been told to authorize personally every drawing that was sent out. If his days were not numbered the hairs on his head certainly were!

Lack of time prevented Mr. Barber from answering more than two or three questions, but despite this members and friends present agreed that they had listened to a most interesting and instructive talk. On their way out of the lecture hall visitors were able to inspect samples that had been welded by the various processes mentioned during the evening.

A.C.M.

South London **Chairman's Address**

Speaking to an audience of about 50 members and visitors the new Chairman of the Branch, Mr. J. Hinde, delivered his address on "*The welding of dissimilar metals*". He pointed out that the title covered a wide field but he proposed to deal only with one or two aspects that might be of interest. Mr. Hinde divided the metals that can be welded into three groups: those that are incompatible, those that are compatible, and those that are readily welded together with a third material that is compatible to either.

He spoke of the work that has had to be done for the steam power industry, where ferritic pipes have to be joined to austenitic materials in the system. This has been achieved in several ways, in which welding has played a prominent part. Mr. Hinde indicated that the diffusion of carbon across the joint was a significant factor in this connection, and one method of avoiding it was to insert a layer of nickel between the two steels.

Dealing with an entirely different industry, he spoke of the widely used method of cladding mild steel vessels with a corrosion-resistant material such as stainless steel, and referred to methods of welding such plates. Likewise, the author spoke of the developments that had taken place in the lining of chemical vessels for a similar purpose, and mentioned that austenitic steel or nickel alloys are frequently used on the inside of chemical plant, although often the lining was in fact not joined to the outer shell of the vessel. The welding procedures have to be specially developed, and the author showed some slides dealing with this aspect. He referred also to progress in the welding of non-ferrous tubes into tube plates in the field of condensers and heat exchangers. Frequently, different alloys are used for the two components, and mention was made of the new automatic argonarc methods under development. In regard to the processes ancillary to welding, the author mentioned brazing, which was becoming an important method of joining dissimilar metals, and bronze welding, which he felt was a slight misnomer.

In the discussion, speakers referred to other methods of joining dissimilar metals, such as by flash welding and by ultrasonics. Mr. Houldcroft, a welcome visitor to the Branch, spoke of some methods he had recently seen in the U.S.S.R., and gave a few details of the friction welding process used there. Another visitor gave further details on the welding of tube to tube plates by automatic means.

Mr. W. K. B. Marshall proposed a vote of thanks to Mr. Hinde. For this meeting, the Vice-Chairman of the Branch, Mr. G. M. Boyd, presided.

Publicity

The Committee of the South London Branch has been discussing means of improving the meetings for the current session, and for publicising them. A personal letter has been sent to every Branch member inviting a greater interest in the affairs of their organization. A mixed programme has been specially arranged so that there should be at least one meeting to interest each member through the session.

The meeting in November was on "*Small Ship Construction*", and that in December is a joint meeting with the North London Branch on the "*Welding of Pipelines*".

N.T.B.

Sessional Programmes

South Wales

17th Oct.—"*Improved steels and their weldability*" by F. J. Wilkinson (Swansea)
18th Oct.—"*Improved steels and their weldability*" by F. J. Wilkinson (Cardiff)
6th Dec.—"*The importance of welding research for industry*" by A. A. Wells (Swansea)
12th Dec.—"*Consumable arc welding*" by D. B. Tait (Cardiff)
16th Jan.—"*Tubular construction*" by R. G. Taylor (Neath, Technical College)
17th Jan.—"*Tubular construction*" by R. G. Taylor (Newport, Tubewrights Ltd.)
20th Feb.—"*Economic aspects of various fusion welding processes*" by W. D. Waller (Cardiff)
21st Feb.—"*Economic aspects of various fusion welding processes*" by W. D. Waller (Swansea)
2nd March—"*Welding in marine engineering*" by J. A. Dorrat (Cardiff)
3rd March—"*Welding in marine engineering*" by J. A. Dorrat (Swansea)
24th March—Annual Dinner (Angel Hotel, Cardiff)

Meetings start at 7.0 p.m. Those at Cardiff are held at the Institute of Engineers; those at Swansea are held at the Technical College.

NEWS FROM INDUSTRY

Soviet Welding Delegation to the U.K.

As announced in the October News (p. 663) a Soviet Welding Delegation, led by Dr. B. E. Paton, Academician of the Ukrainian Academy of Sciences and Director of the Soviet Welding Institute, visited the U.K. in mid-September, and left for Moscow on 8th October. This was a reciprocal visit following that of the delegation from the British Welding Industry to the U.S.S.R. in June. The exchange of visits was arranged by the

Soviet welding technologists at the BWRA Research Laboratories, Abington. Left to right: *Dr A. A. Wells (BWRA); Mr. V. P. Andreev; Major J. H. Dixon (Interpreter); Mr. M. I. Baranov; Mr. V. P. Sokolov; Mr. R. Pendrous (BEAMA); Mr. A. O'Neill (BWRA); Mr. P. T. Houldcroft (BWRA); Dr. B. E. Paton (Leader of Soviet team); Mr. R. G. Burt (BWRA); Mr. L. B. Kolesnikov (Interpreter); Dr. R. Weck (BWRA); and Dr. I. K. Pokhodnya.*

British Electrical and Allied Manufacturers' Association.

The delegation visited many firms, including welding supplies manufacturers as well as fabricators, and the members were impressed by the standard of welding used in construction and the skill of the operators. Nonetheless, Dr. Paton stated that they were surprised to see so much riveting going on side by side with welding. This might be because of the conservatism of clients or that welding engineers did not sufficiently enlighten them about the advantages of welded construction.

The Soviet technologists were enthusiastic about the large specialized plants they visited, for they considered that these allowed the latest types of equipment to be used with consequent economic advantages. In the Soviet Union there was a tendency to concentrate on certain welding techniques that provided a large degree of automation, and the delegation believed that there were great possibilities in the U.K. for similar developments; for example, submerged-arc and gas-shielded processes (particularly CO_2) could be used on a much larger scale.

It would seem that the quality of electrodes and the standard of electrode production are much higher in Britain than in the U.S.S.R., but the Soviet delegates considered that the very wide range of welding equipment used in British industry was an impediment to progress in comparison with the Soviet aim of increasing the production of a limited number of types to be used throughout industry.

In regard to the future, Dr. Paton believed that there would be an increase in the automatic control of the welding process, followed by the programming of the whole operation, as is being done in other forms of production.

As reported in the November News (p. 686) the Soviet delegation attended a reception at the Institute of Welding just before their departure. Two days previously the members visited the Abington Research Laboratories of the British Welding Research Association, where they were able to discuss comparative approaches to welding research. They were impressed by the extensive studies of the strength of welded components being undertaken at Abington, but were again surprised that CO_2-shielded welding was more advanced in the Soviet Union than in Britain.

Welding Research and Practice in the U.S.S.R.

During September a composite team of British welding experts from the Institute and the British Welding Research Association, led by Mr. E. Seymour-Semper (Hancock & Co. (Engineers) Ltd.), a Past-President of the Institute, visited research establishments and various engineering works in the U.S.S.R. The Mission was organized under the auspices of the U.S.S.R. State Scientific and Technical Committee, through the British Embassy.

In addition to Mr. Seymour-Semper, the Institute nominated E. V. Beatson (Joseph Lucas Ltd.), E. F. Burford (G. A. Harvey & Co. (London) Ltd.), J. A. Dorrat (Richardsons, Westgarth & Co. Ltd.), and W. C. Holliday (Whessoe Ltd.).

Dr. R. Weck led the B.W.R.A. group, consisting of P. T. Houldcroft, H. F. Tremlett, and Dr. A. A. Wells.

The visit was arranged to coincide with the opening of a Welding Exhibition within the permanent Moscow Exhibition of Economic Achievements in the U.S.S.R. Other places visited were:

A. A. Baikov Institute of Metallurgy, Moscow
M. V. T. U. Baumann Higher Technical School, Moscow
Kherson Shipbuilding Co., Kherson
Likhachev Automobile Works, Moscow
Metallicheskii zavod Turbine Works, Leningrad
E. O. Paton Arc Welding Institute, Kiev
TsNIITMASh Central Research Institute for Plant and Machinery Construction, Moscow
VNIIESO Central Research Institute for Electric Welding Equipment, Leningrad

At the Welding Exhibition automation and mechanization of welding processes was the dominant theme, and the team was impressed by the high standard of the exhibits, particularly in the recently developed welding equipment. Here, and in the various works visited, there was much evidence of the Soviet appreciation of the importance of welding in modern engineering and construction.

Considerable use is made of submerged-arc welding, generally with thin wires and making heavy deposits. The process has been adapted for strip or layer welding for surfacing and cladding and with the development of suitable fluxes it has been applied to the welding of non-ferrous materials, such as aluminium and titanium alloys and copper.

In like manner, the gas-shielded metal-arc processes, using CO_2 and argon, have been highly developed and are widely used, generally in semi-automatic or fully automatic form. It was noticed, however, that the inert-gas process was not used for the welding of aluminium alloys to the same extent as in Britain.

Resistance welding is applied in normal conditions and in some exceptional ones. For instance, the team saw a portable flash welder with a contour transformer, which was used for the site welding of pipes up to 700 mm dia.

Since many districts in the U.S.S.R. are not supplied with adequate power for heavy welding plant there have been developments in the field of friction welding. In this method (which can be applied only to objects of circular profile) fusion is attained by the mechanical rotation of one part against the other

under pressure. When sufficient frictional heat has been developed the rotation is stopped and the parts are forged together. The efficiency of the process in producing the required heat means that only relatively low electrical power is needed. The same economic factors have resulted in the development of other alternative processes; for example, the use of steam as the shielding gas in bare wire welding instead of argon or CO_2. But in contrast there are other more specialized developments; electron beam welding is used for the fabrication of the rarer metals; diffusion welding—the application of heat and pressure in a vacuum—is used for joining metallic and non-metallic materials; and cold pressure welding is used for joining dissimilar metals.

In the field of fabrication the team was particularly interested in the prefabrication and erection of large vertical storage tanks. These are welded in the shops as flat sheets for the sides and bottom, and are then rolled up for transport. At the site the rolls are opened by means of tractors, and the tanks are erected with the minimum of site welding. Pipelines are dealt with in a similar way; they are welded flat, in strip form, transported to the site in rolls, and then by a combination of tractor unwinding and pneumatic pressurizing the pipes are laid at site.

In the shipyards at Kherson there was much evidence of mechanization, and standard type vessels are produced almost with a conveyer-line technique.

In general, the quality of welding in the U.S.S.R. is good, but acceptance standards are lower than in Britain. On the other hand, the Soviet engineers are more concerned with fitness for purpose than appearance, and there is perhaps a closer liaison in the Soviet Union between research, development, production, and the training of welding personnel and supervisors than in Britain.

Research is more applied than fundamental and is devoted mainly to the development of new processes and techniques right up to the production stage. There seems to be far less delay between the development of a new process and the availability of suitable machines in industry than is the case in Britain. This is probably because the Soviet research workers have such excellent facilities for the manufacture of prototypes and actual production machines.

Great importance is attached to the need for fully trained technologists and technicians in all production processes involving welding. Thus the Soviet Union has a big educational programme, and considerable emphasis is placed on education in welding technology at all levels. A recent decree has ordained that every plant using welding as a production process must have a qualified welding engineer on the staff. Such a directive would be impossible in Britain, for there is as yet no recognized qualification for a welding engineer.

B.O.C. Evolution

The several member companies of the British Oxygen Group—British Oxygen Gases Ltd., British Oxygen Engineering Ltd., British Oxygen Research and Development Ltd., Quasi-Arc Ltd., Sparklets Ltd., and A. Charles King Ltd.—which have been trading under their own names within the Group, are now consolidated in the one parent company, The British Oxygen Company Ltd.

The B.O.C. resumed trading under its own name on 1st October 1960, and the original member companies will act as agents for the parent company until 31st December 1960.

The reorganization has been made to re-align the widespread activities of the Group in the United Kingdom in the most effective pattern, and the Company's full resources are now available to all the new functional Divisions. Thus, the new Operating Division will be concerned with all the company's gas producing works in the U.K. (previously operated by British Oxygen Gases Ltd.), and electrode manufacture (previously the province of Quasi-Arc Ltd.).

The Sales Division, under Mr. J. Strong, will be responsible for all Group selling activities in the U.K., excluding chemicals, for which there is a separate Division.

Likewise, a new Technical Division, with Dr. N. Gross as Chief Executive, will increase the emphasis on technical development of products and processes concerning the whole of the home and export sales effort. The existing technical centre at Cricklewood is being expanded so as to give full facilities to this important Division.

An important decision of the Company is to retain all current trade names and trade marks. This means, especially in the welding field, that such 'household' names as Quasi-Arc, Fusarc, and the like will not be lost, even though they will now be more closely associated with the title 'The British Oxygen Company Ltd.'

One associated company remains the same: British Industrial Gases Ltd., with its close connections with the American Harris Calorific Company, will continue to trade as a separate entity.

Apart from the obvious administrative advantages to the Company itself, it is considered that the new organization will be appreciated in industry. Greater resources than ever before can be devoted by the Group to the development and promotion of all its products and processes, especially in the field of welding and cutting. An important, though perhaps relatively minor feature of the reorganization is that all the sales offices and stores of the former member companies will now be available for all products and divisions of the Group. This will undoubtedly increase the service to customers throughout the country, and will speed delivery of goods.

Reduced price of Welding Controls

Lancashire Dynamo Electronic Products Ltd. have announced price reductions to their range of resistance welding controls, Series CRW.1. The reductions, which average 10% on previous list prices, are made possible by improved manufacturing methods and increased production.

These controls provide a range of 42 different types of equipment in a common basic cubicle assembly, including installations for synchronous spot, seam and pulsation welding. Printed circuits are used in the standard sub-units which, with plug and socket inter-connections, simplify maintenance.

Register of Standards Associates

A meeting held recently at British Standards House in London, of over 100 engineers and others concerned with the application of standards in industry, gave its support to a new scheme sponsored by the British Standards Institution for a "Register of Standards Associates".

The objects of the scheme are to provide a forum for those connected with standards matters, to increase knowledge and to develop techniques so as to further the aims and practice of standardization, generally through discussion and dissemination of information.

Those on the Register will become associates of the B.S.I. They will receive copies of *B.S.I. News* each month, a list of the names on the Register from time to time, and possibly a special bulletin.

The initial annual subscription to join the Register is one guinea, which should be sent, together with the applicant's address for correspondence, the name of his organization and his position in it, to the Joint Secretary, I.Prod.E./B.S.I. Committee, British Standards Institution, 2 Park Street, London W.1.

Alcan Industries Ltd.

As from 15th September 1960, Northern Aluminium Co. Ltd. has been known as Alcan Industries Ltd. This new name involves no change of ownership, manufacturing activity, or sales policy. Its purpose is simply to identify the company clearly as a member of the Aluminium Ltd. of Canada enterprise—'Alcan' for short.

Northern Aluminium Co. Ltd. was incorporated more than fifty years ago and is Aluminium Ltd's principal fabricating company converting Alcan ingot into sheet, plate, sections, forgings, castings, and other forms.

Over the years, the products of Northern Aluminium Company have become well known under the 'Noral' mark, and Alcan Industries Ltd. propose to continue to use this trade name.

NEW PLANT AND EQUIPMENT

Argonarc spot welding

A new prototype argonarc spot welding torch was shown by the British Oxygen Co. Ltd. at the Farnborough Air Show and again at the Commercial Motor Show.

With the new torch, which will supersede the present standard torch early in 1961, access to only one side of the components is needed, and welds can be made with one hand and by semi-skilled labour.

The water-cooled torch can accommodate currents up to 250 amp, and the tungsten electrodes can be changed or adjusted simply and quickly without removal of the ceramic adaptor or argon shield. Interchangeable nozzles enable the torch to be used in the horizontal and vertical positions and on narrow flanges or on right-angled outside corner joints.

The process is semi-automatic once the welding conditions have been preset.

Cover illustration

Argonarc spot welding of aluminium sheet

STUB ENDS

▶Electrodes marketed by Stubs Welding Ltd. cover a wide range of welding applications, including cast iron, aluminium, bronze, copper, stainless steel, steel alloys and hard-facing. Brazing of galvanized iron without burning off the zinc—always considered a difficult problem—can be achieved quite easily with their No.1 Gas Rod. A recent catalogue gives details of these electrodes.

▶I.C.I. have announced further major reductions in the basic prices of their wrought titanium, as from 1st November 1960.

▶The alloy tube manufacturing business of Booth and Mapplebeck Ltd. has been acquired by Yorkshire Imperial Metals Ltd.

▶A metal-testing service has been set up in Newcastle under the name of Copley Metal Testing Ltd. The organization covers comprehensive non-destructive testing, chemical analysis, and physical testing, and operates throughout the U.K.

▶Two new kinds of rubber pressure hose, designed to give increased safety, are being marketed by British Industrial Gases Ltd., Enfield. One is for use with gas cylinders and equipment, and the other is specially designed for use with propane.

▶A contract for welding supervision services over approximately 800 miles of 14 in. and 18 in. pipeline has been placed with Solus-Schall Ltd. by Burma Oil Co. (Pipelines) Ltd., on behalf of Oil India.

Conferences and Exhibitions

● The 6th International Conference on Hot Dip Galvanizing is to be held at Interlaken, Switzerland, from 4th to 9th June 1961. The welding of galvanized steel is to be included in the technical discussion. Further information is obtainable from the Zinc Development Association, 34 Berkeley Square, London W.1.

● The 2nd International Compressed Air and Hydraulics Exhibition, sponsored by *Fluid Power*, will be held at Olympia from 30th April to 4th May 1962.

● The 2nd International Pipes and Pipelines Exhibition, sponsored by Scientific Surveys Ltd., has been planned for Earls Court, commencing on 9th April 1962.

CORRECTIONS

● **Advertiser's correction:** Messer Industrial Engineering Ltd. have informed us that there is an error in their advertisement which appears on p. 27 of the October issue. In fact, 16,000 (not 1600) Quicky machines have been sold all over the world.

● In the news item concerning the lectures given at the IIW Annual Assembly at Liège (November issue, p.688), it was reported that the author of Paper 5 in Commission I was A. Richard. We are now informed that the correct name of this author is A. R. Old of Charles D. Holmes & Co. Ltd.

DIARY

1st Dec.—Birmingham—Annual Dinner (Grand Hotel, Birmingham)
N.E. Tyneside—"*Electro-slag process*" by D. J. W. Boag (Mining Institute, Newcastle, 7.0 p.m.)

3rd Dec.—N.E. Tyneside—Branch Dinner

5th Dec.—Preston—"*Pipeline welding*" by R. J. Wright (Lancaster Technical College, 7.15 p.m.)
South Western — Welding Forum (Radiant House, Bristol, 7.15 p.m.)

6th Dec.—North London (Slough Section)—"*Argon welding process*" by F. W. Copleston (Lecture Room, Community Centre, Farnham Road, Slough, 7.30 p.m.)
South Wales—"*The importance of welding research for industry*" by A. A. Wells. (Swansea Technical College, 7.0 p.m.)

7th Dec.—Manchester—"*Automatic welding*" by J. A. Lucey (Reynolds Hall, College of Science and Technology, Manchester, 7.15. p.m.)
Wolverhampton—"*Welding and physical metallurgy*" by T. Fullwood (Wulfrunians Club, 7.30 p.m.)

8th Dec.—Southern Counties—"*Welding of motor car bodies*" by J. H. J. Church (Technical College, Southampton)
Leeds—Annual Dinner (Hotel Metropole, Leeds, 7.30 p.m.)
Institution of Structural Engineers—"*The Runcorn/Widnes Bridge project*" by J. K. Anderson (College of Science and Technology, Manchester, 6.30 p.m.)

9th Dec. — Birmingham — Lecturettes: "*Fine wire welding*" by D. B. Tait; "*Electro-slag welding*" by C. A. Burden; "*Plasma jets*" by R. Cresswell (Grand Hotel, Birmingham, 7.30 p.m.)
South Western — Annual Dinner (Grand Hotel, Broad Street, Bristol)

12th Dec.—N.E. Tees-side—"*Design, fabrication and assembly of walking dragline excavators*" by C. McL. Cameron (Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, 7.30 p.m.)
Sheffield—"*British Railways welding of railway rolling stock*" by G. Walton. Joint meeting with the Inst. of Production Engineers, Sheffield section.
South Wales—"*Consumable arc welding*" by D. B. Tait (Institute of Engineers, Cardiff, 7.0 p.m.)

13th Dec.—East Midlands—"*Electro-slag welding*" by W. K. B. Marshall (Nottingham)
Liverpool—"*The practice of metallizing*". Demonstration by E. W. Whitelock, lecture by H. F. Smith (College of Technology, Byrom Street, 7.15 p.m.)

14th Dec.—North London—Joint meeting with South London Branch. "*Welding of transportation pipelines*" by R. J. Wright (54 Princes Gate, S.W.7, 7.30 p.m.)

15th Dec.—Leeds—"*Brazing and copper welding*" by G. F. Charge (Hotel Metropole, Leeds, 7.30 p.m.)
Eastern Counties—"*A look into modern welding processes*" by A. A. Smith (Ipswich)

21st Dec.—West of Scotland—"*Electro-slc welding*" by A. M. Horsfield (I. tution of Engineers & Shipbuilders, 39 Elmbank Crescent, Glasgow C.2, 7.0 p.m.)

4th Jan.—Manchester—"*Pipeline welding*" by R. J. Wright (Reynolds Hall, College of Science and Technology, Manchester, 7.15 p.m.)

5th Jan.—Institute of Welding—Second Annual Lecture for Young People, by Prof. J. G. Ball (54 Princes Gate, S.W.7, 11.0 a.m.)
N.E. Tyneside—"*Some special applications of welding in steam, gas turbine, and nuclear power plants*" by Dr. J. M. Robertson (Mining Institute, Newcastle, 7.0 p.m.)

9th Jan.—N.E. Tees-side—"*Weld interpretation by radiographic methods*" by T. W. Brown (Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, 7.30 p.m.)
Sheffield — Annual Branch Dinner (Royal Victoria Hotel)
South Western — "*Future of gas shielded welding*" by A. A. Smith (Radiant House, Bristol, 7.15 p.m.)

NON-DESTRUCTIVE TESTING

Palmer

NON-DESTRUCTIVE TEST SERVICE

X-Ray and Gamma-Ray service (Test House and Mobile) ★ Magnetic crack testing Fluorescent crack testing ★ Ultra-sonic testing ★ Pressure testing—air and hydraulic ★ Low temperature testing ★ Film processing and radiological reports

Palmer Aero Products Ltd

AERO PRODUCTS DIVISION BTR INDUSTRIES LIMITED
PENFOLD STREET · LONDON N.W.8 TEL: PADDINGTON 6822 6/3121A

ULTRASONOSCOPE CO. (London) LTD.

One of the pioneer teams offer the complete Ultrasonic testing service:

★ Manufacturers of Ultrasonic Flaw Detectors
★ Consultants in Ultrasonic Flaw Detection
★ Ultrasonic Inspection Service
★ Designers of Special Equipment

SUDBOURNE ROAD, BRIXTON HILL, LONDON, S.W.2 Tel: BRIxton 4041

Revolutionise your entire inspection and quality control programme with:

XERORADIOGRAPHY

– the new process which reduces inspection time and makes 100% inspection economical.
For further information please write to:

RANK XEROX LTD.,
33–41 Mortimer Street
LONDON W1
Telephone No: MUS 5432

RADIOGRAPHY

on site —
— in your works —
—in our LABORATORY
at BLD 48

HEAD OFFICE
BIX. LTD C **LONDON AIRPORT**
73 HIGH HOLBORN A **HOUNSLOW**
LONDON, WC1 L **MIDDX**
CHA 4183 ←L→ **SKY 1537**

NON-DESTRUCTIVE WELD EXAMINATION

The School of Welding Technology will hold a course on this subject from 13th to 17th February 1961 inclusive at the Institute of Welding. For further details of this and other courses send for prospectus.

Dept. NDE. INSTITUTE OF WELDING
54 Princes Gate, Exhibition Road
London S.W.7.

INSPECTION SERVICES LTD
Oldfields Trading Estate
Sutton By-Pass, Sutton, Surrey.

NON-DESTRUCTIVE EXAMINATION OF WELDING CONCRETE, ETC., BY X-RAY, GAMMA RAY, ULTRASONIC AND CRACK DETECTION
A.I.D. APPROVED TEST HOUSE

Telephone: Fairlands 4546.

MANCHESTER OIL REFINERY (SALES) LTD

76 Jermyn Street, London, S.W.1

Specialists in non-destructive testing by the Electromagnetic and penetrant methods.
Supramor and Lumor magnetic inks.
Britemor and Glomor fluorescent penetrants.
Verimor and Verimor (Solvent Process) dye penetrants.
Devmor (High Flash Developer).

THE ARDROX No. 996

FLAW DETECTION KIT

Using self spraying aerosol dispensers. A.I.D. approved process for all crack detection on welds, bar and sheet.

BRENT CHEMICAL PRODUCTS LTD
COMMERCE ROAD, BRENTFORD, MIDDLESEX
Telephone: ISL. 5444/5/6

MAPEL MEN are skilled in the supervision and inspection of welding, using either visual, x-ray, gamma-ray, ultrasonic or other non-destructive methods.

Inspection of steel structures, tanks, pressure vessels, pipelines, and welded or fabricated equipment, can be undertaken to any specification.

THE WATCHFUL EYE OF MAPEL WELDING INSPECTION SERVICE CAN PROTECT YOU

Contact

MAPEL

World Wide Service

METAL AND PIPELINE ENDURANCE LTD

London Road, Woolmer Green, Hertfordshire
Telephone: Knebworth 3083 Telegrams: Metaldure, Knebworth

Other Offices at London, Newcastle-upon-Tyne and Glasgow

RESISTANCE WELDING MACHINES

A COMPREHENSIVE RANGE OF MACHINES CAN BE SEEN
IN OUR WELDING DEMONSTRATION WORKSHOP
WE INVITE YOUR ENQUIRIES

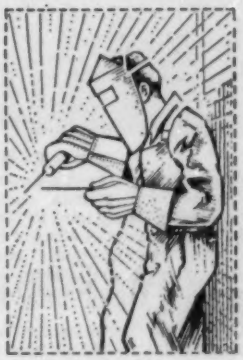
MERITUS (BARNET) LTD.

BARNET, HERTS. BAR. 2291/2

Gold Medal and Bronze Medal. Brussels World Exhibition 1958. The Engineering Centre Collective Exhibit.

Footmen are aloof to Bennett's gloves—

but they're vital for jobs **'on hand'**



A wide range of quality industrial Gloves, Mitts, Aprons and Clothing in leather, rubber, asbestos, plastic and various fabric materials are made and stocked for all trades and processes. Technical Representatives are available for consultation in all parts of the British Isles at short notice.

BENNETT'S
INDUSTRIAL GLOVES

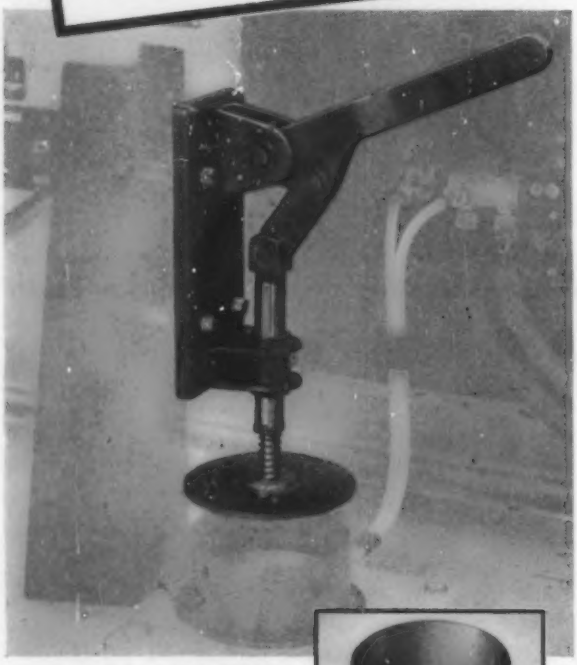
H. G. BENNETT & CO. (Gloves) LTD. · Industrial Glove Specialists · LIVERPOOL 23 · GREat Crosby 3996/7

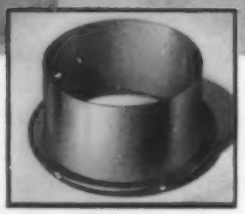
CVS-16

BRAUER 'Quick-Action' TOGGLE CLAMPS

for the Electronics Industry can be made in special Non-Ferrous Non-Magnetic materials. Wherever used, BRAUER TOGGLE CLAMPS save thousands of man hours with their fast, powerful and accurate holding.

FOR QUICKNESS AND POWER USE CLAMPS BY BRAUER





BRAZING

The illustration shows a BRAUER 'Quick-Action' TOGGLE CLAMP Type TC.62 being used to meet the requirements of efficient induction brazing – quick positive clamping and instant releasing – at Radio Heaters Ltd., Wokingham.

This brazing fixture incorporating a BRAUER Clamp has achieved considerable saving of time and money in the production of meter cases (see inset photograph).

Send now for illustrated catalogue and technical data to Dept. 28.

F. BRAUER LTD., HARPENDEN, HERTS.

Member of the Cope Allman Group

Makers of Europe's largest range of Toggle Clamps

FW3

COURTBURN SUPPLIES LIMITED

the welders ★ choice

Electrode holders

★ **Can be laid down without arcing.**
★ **Makes the awkward spot accessible.**
★ **Uses nearly all the electrode.**

The light and easy handling of the Electrode Holder makes it the welder's choice.

Supplied to internationally known Companies, the two types, Prong Fixing and Screw Fixing, each come in two different sizes, 400 amp. and 600 amp. Capacity, with all parts replaceable.

The holders are available on trial for test purposes, and all spares can be despatched immediately, on request.

COURTBURN SUPPLIES LTD.

Stanley Works, Kempston Hardwick, Bedford. Telephone: Kempston 2341

RESISTANCE WELDING CURRENT METER

Designed to measure short pulses of heavy current

The standard instrument has 6 ranges covering readings of 100 to 100,000 amps. The readings are obtained by the use of toroids which can be split and placed around the heavy current conductor. Indication is stored enabling readings to be taken minutes after the weld is made.

Can be used with welders employing synchronous and non-synchronous and energy storage controls.

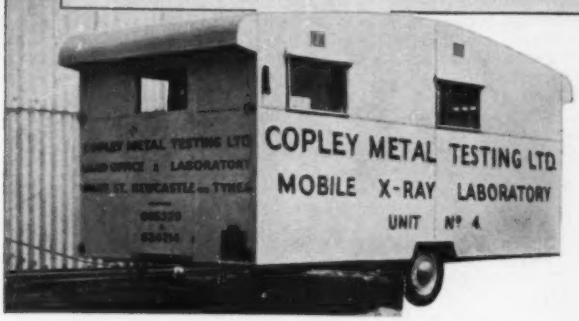
Illustrated leaflet sent on request

HED

HIRST ELECTRONIC LTD.

GATWICK ROAD, CRAWLEY, SUSSEX

Mobility *plus* Service – *thats Copley*



This mobile laboratory is completely equipped for the most exacting tests

In your Works . . .

A Copley Mobile Laboratory is on call at almost any hour of the day to undertake tests in your works. It is worth finding out how we replace guesswork with certainty. A consultation puts you under no obligation whatsoever. Write, call or telephone today.

On the Site . . .

We can test your work wherever one of our mobile units can penetrate. Distance is no object—our staff take a pride in making even the most difficult assignment *on time*. Mobility plus service—that's Copley.

- *Welding Supervision*
- *X-ray and Gamma Ray*
- *Ultrasonic Flaw Detection*
- *Leak Detection by Radioactive Isotopes*
- *Magnetic and Penetrant Dyes*
- *Marine Thickness Measurement*

COPLEY METAL TESTING LIMITED

WHITE STREET · NEWCASTLE UPON TYNE 6.

Telephone: Newcastle 624214 & 666529

SCHOOL OF WELDING TECHNOLOGY

EVENING COURSES *for designers and draughtsmen*

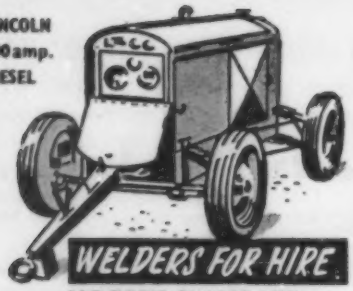
Detail Design of Welded Structures • **BIRMINGHAM**

Welding Design in Heavy Engineering • **MANCHESTER**

PROSPECTUS AND ENROLMENT FORM ▶

SCHOOL OF WELDING TECHNOLOGY
THE INSTITUTE OF WELDING
54 PRINCES GATE
LONDON, S.W.7

CLASSIFIED ADVERTISEMENTS



MOORE'S PLANT LTD.

105-129, MARKFIELD ROAD TOTTENHAM LONDON N.15

RING TOTTENHAM 0401

dm M 0107/1

FASSLER MOTOR DRIVEN STITCH WELDING MACHINE Type PF40, for sale, 40 kVA. Suitable for 415 volts, 50 cycles. Capacity ¼ in. added thickness. Depth of gap 24 in. Reeves variable speed drive. Four heating speeds. Full details from F. J. Edwards Limited, 359 Euston Road, London, NW1, or 41 Water Street, Birmingham 3.

'MUREX' STATIC TRANSFORMER ELECTRIC ARC WELDING PLANT for sale. 16 kVA. For two operators. On four-wheel truck 200/440 volts, single phase. Range 80 volts 30/205 amps; 100 volts 35/210 amps. F. J. Edwards Limited, 359 Euston Road, London N.W.1, or 41 Water Street, Birmingham 3.

SERVICES OFFERED

FACTORY TIME RECORDERS. Rental service. Phone: Hop 2239. Time Recorder Supply and Maintenance Co. Ltd., 157–159 Borough High Street, London S.E.1.

'B.I.C.' No. 131 LONGITUDINAL SEAM WELDING MACHINE for sale. Specially suited for work which may be fed into the machine throat, side or straight seams on cylinders or drums. All electrical equipment suitable for 400 volts, 50 cycles. Maximum power required 12 kW. Two thicknesses of 20 S.W.G. Number of heating speeds 8. Depth of throat 24 in. Photo and details from F. J. Edwards Limited, 359 Euston Road, London, NW1, or 41 Water Street, Birmingham 3.

BRAND NEW OIL-IMMERSED OXFORD ARC WELDING TRANSFORMERS WILL GIVE YOU A LIFETIME OF SERVICE.

Fully guaranteed sets—110 amp £25, 180 amp £45, 250 amp £71, 300 amp £85, 350 amp £99 10s., 450 amp £135, etc. Also Two-operator 180, 250 and 300 amp Models, ex stock.

Send for leaflets and booklet from Britain's largest electric welding plant stockists.

C. G. & W. YOUNG

15A COLNE ROAD, TWICKENHAM. POP. 5168

SCIAKY TYPE RAMC 2/40 CIRCUMFERENTIAL OR END SEAM PNEUMATIC WELDING MACHINE for sale. Specially suitable for welding the ends of cylinders or drums and for straight runs. Pneumatic electrode pressure. Bottom electrode wheel driven in either direction with variable speed chain drive. Nominal rating 40 kVA. Capacity two thicknesses of 18 S.W.G. Welding speed from 2 to 9 ft per minute. Depth of throat 14½ in. Photo etc., from F. J. Edwards Limited, 359/361 Euston Road, London, NW1, or 41 Water Street, Birmingham 3.

NEW 200-TONS PRESS BRAKE IMMEDIATE DELIVERY, subject to prior sale. Thickness formed ½ in. × 167 in. over 2 in. die opening. Maximum working length 13 ft 11 in. Between uprights 11 ft 8 in. Steel plate construction. Motor drive. Weight about 25½ tons. An excellent machine. Full details, illustrations, from F. J. Edwards Limited, 359 Euston Road, London, N.W.1, or 41 Water Street, Birmingham 3.

REPRESENTATIVES FOR GAS WELDING & CUTTING EQUIPMENT. PERMANENT APPOINTMENT WITH PROGRESSIVE OPPORTUNITIES. SALARY AND COMMISSION IN RELATION TO PREVIOUS SIMILAR EXPERIENCE WHICH IS ESSENTIAL.

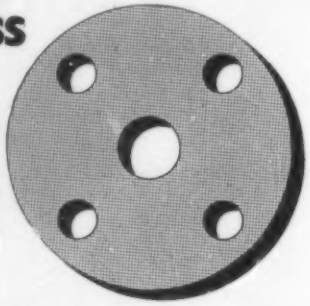
Write PRESSURE CONTROL LTD., Davis Road, Chessington, Surrey.

FOREMAN

capable of organizing and working on own initiative required for Fabrication Dept. of Electric Motor Manufacturers. Applicants must have good knowledge of both electric and gas welding and cutting techniques and able to apply modern production methods for jobbing and batch production. Full details to Works Director, Electro Dynamic Construction Co. Ltd., St. Mary Cray, Orpington, Kent.

A firm of chemical engineers in the south has a vacancy for a RADIOLOGIST experienced in industrial radiography of light alloys and of ferrous alloys. A.I.D. approval for light alloy work is essential. A four figure salary is envisaged for a suitable man, and pension and profit sharing schemes are operated. Reply in strict confidence to Box No. 251.

STAINLESS TUBES & FLANGES



We offer in approved grades of Stainless Steel

★ **FLANGES MACHINED TO B.S. TABLES OR TO SPECIAL SIZES**

★ **SOLID DRAWN TUBES – FABRICATED PIPES**

★ **ROUND and HEXAGON BAR**

★ **PROFILES CUT TO ANY THICKNESS OR SIZE**

★ **CASTINGS TO CUSTOMERS' SPECIFICATION**

Keen Prices – Prompt Delivery

Send enquires to Dept. B.W.J.

STAINLESS STEEL PROFILE CUTTERS LTD.

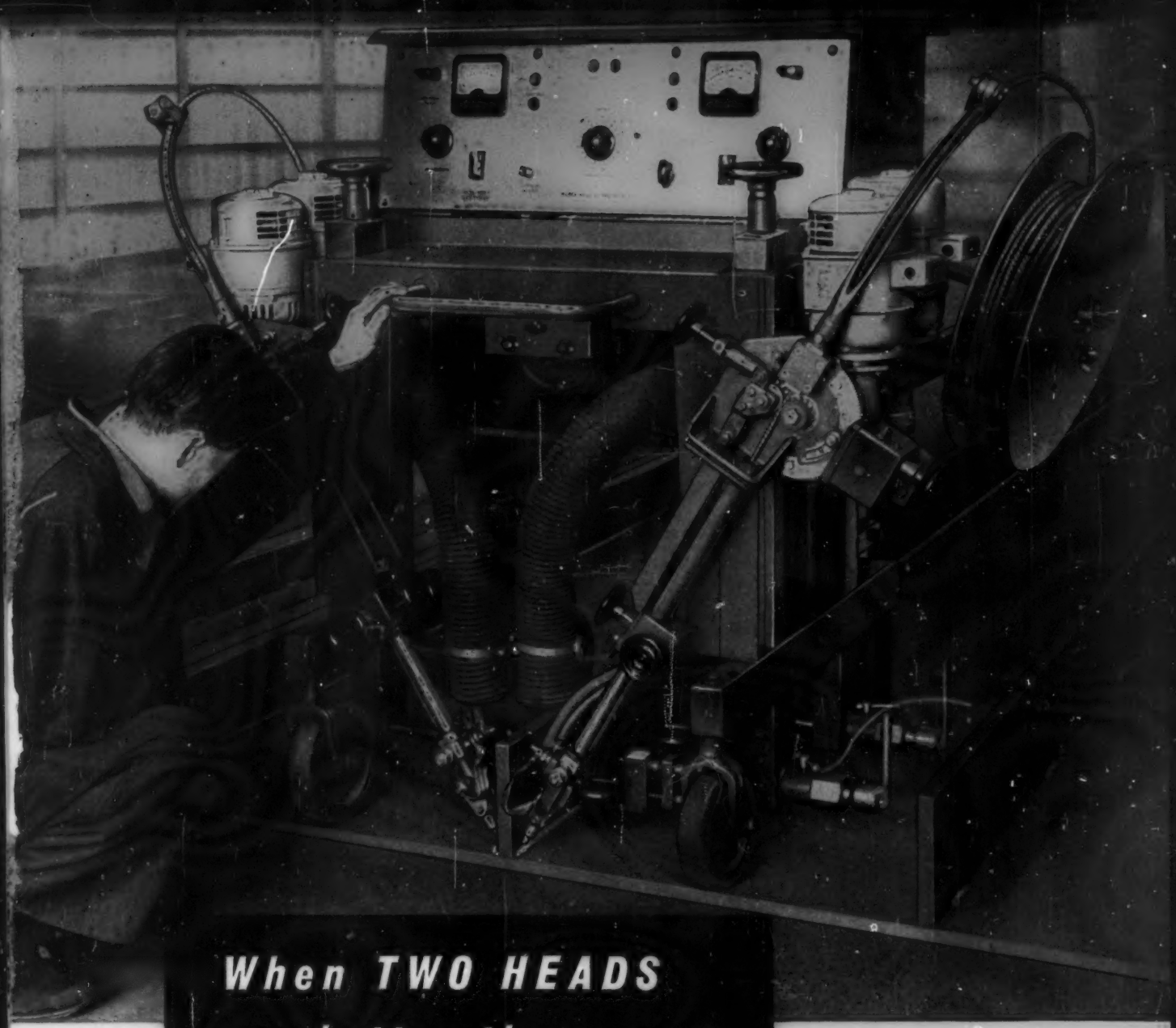
Farfac Works, Kings Grove, MAIDENHEAD

Telephone: 1522/23

ADVERTISERS' INDEX

Associated Electrical Industries	
Electronic Apparatus Division	5
Instrumentation Division	14
Transformer Division	8
Bennett, H. G. & Co. (Gloves) Ltd.	27
B.I.X. Ltd.	25
Brauer, F., Ltd.	28
Brent Chemical Products Ltd.	25
British Oxygen Co. Ltd.	*outside back cover*, 18
Classified	30
Cooper & Turner Ltd.	12
Copley Metal Testing Ltd.	29
Courtburn Supplies Ltd.	28
Crompton Parkinson (Stud Welding) Ltd.	6
Distillers Co. Ltd., The	7
Eutectic Welding Alloys Co. Ltd.	10
Hancock & Co. (Engineers) Ltd.	4
Harvey, G. A. & Co. (London) Ltd.	1
Hirst Electronic Ltd.	28
Ilford Ltd.	13
Imperial Chemical Industries Ltd.	3
Inspection Services Ltd.	25
Manchester Oil Refinery (Sales) Ltd.	25
Meritus (Barnet) Ltd.	27
Mersey Cable Works Ltd.	11
Messer Ltd.	22
Metal & Pipeline Endurance Ltd.	26
Millspaugh Ltd.	23
Murex Welding Processes Ltd.	21
Norton Grinding Wheel Co. Ltd.	20
Palmer Aero Products Ltd.	25
Rank Xerox Ltd.	25
Research & Control Instruments Ltd.	*Inside back cover*
Robey & Co. Ltd.	2
Rockweld Ltd.	*Inside front cover*
Saturn Industrial Gases Ltd.	9
Stainless Steel Profile Cutters Ltd.	30
Ultrasonoscope Co. (London) Ltd.	25
Wiggin, Henry, & Co. Ltd.	24
Yates Plant Ltd.	16

Published by THE INSTITUTE OF WELDING, 54 Princes Gate, London, S.W.7
Made and Printed by Percy Lund, Humphries & Co. Ltd., London and Bradford



When TWO HEADS are better than one...

Use a "MURAMATIC" twin-fillet welder

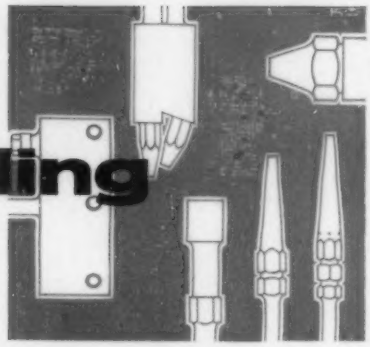
MUREX

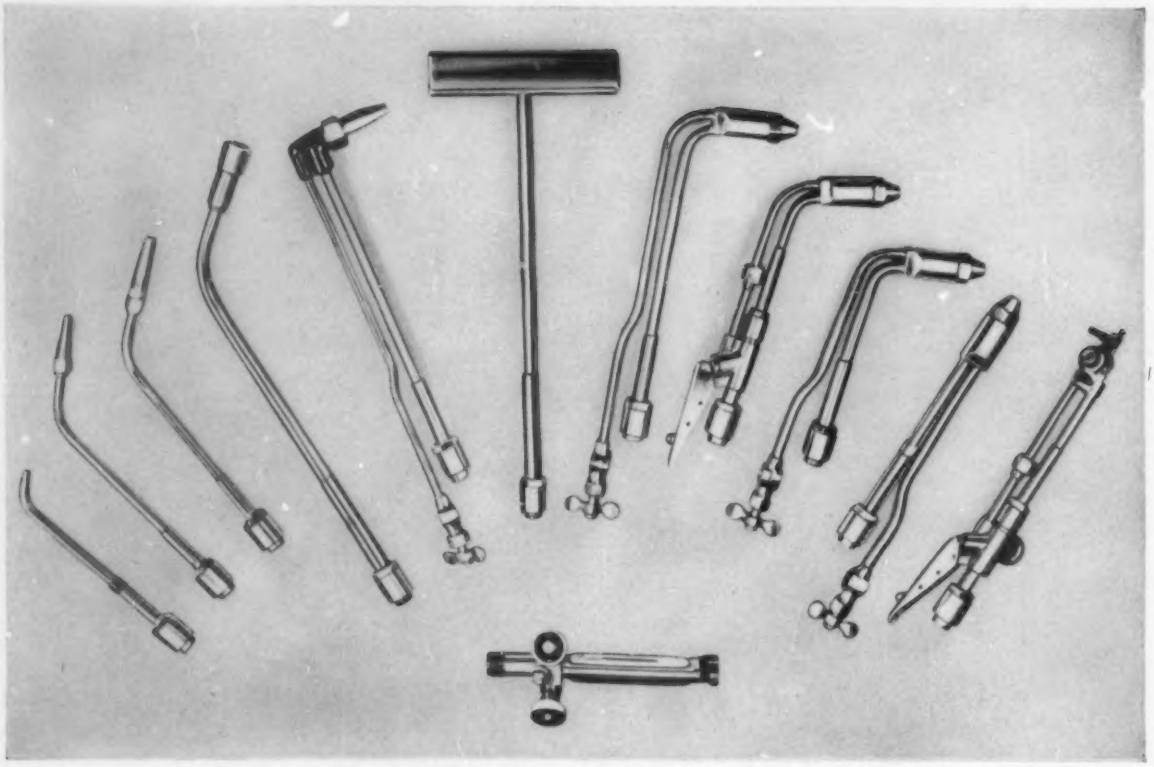
The Murex "Muramatic" automatic fillet welding equipment has been designed to make two horizontal-vertical fillet welds simultaneously on the opposite sides of a stiffener. It consists of two "Muramatic" welding heads mounted on a self-propelled carriage and is suitable for use with the submerged arc process or for the open arc process using a continuous coated electrode. Either alternating current or direct current at any value from 300 to 1200 amps. can be used by each head. The equipment is supplied with all the necessary controls for electrical and mechanical adjustments including the accurate alignment of the welding arcs by guide wheels. Please write for full details.

MUREX WELDING PROCESSES LTD., WALTHAM CROSS, HERTS. Telephone: Waltham Cross 23636

E.31/369

MESSER ...welding





RH/50 Shaft and range of heads

Finely balanced, the unique RH/50 Shaft can be fitted with any of various welding, heating or cutting heads all incorporating the special Messer Injector. This ensures a perfect flame which is virtually non-backfiring under the most arduous conditions.

MESSER Industrial Engineering Limited

43-45 Knight's Hill · London · S.E.27 Telephone: GIPsy Hill 6111

Messer

More information? Ask for a copy of 'THE MESSER STORY'

A Naphthalene Dehydration Vessel of 7,500 gallons capacity, 12 ft. in diameter. Like many supplied by Millspaugh this vessel was subjected to rigorous interstage examination by our clients' appointed inspectors.

BIG FELLOW!

Size *is* important at Millspaugh and fabrications like this 7,500 gallon Naphthalene Dehydration Vessel come pretty often. But quality is the main concern at Millspaugh and some of the most modern and thorough inspection and testing equipment in the country relentlessly makes sure that a Millspaugh Fabrication is one to be relied upon, whichever end of the scale it is—giant size, or relatively small.

WELDING AND FABRICATIONS BY **MILLSPAUGH SHEFFIELD**

MILLSPAUGH LIMITED, ALSING ROAD, SHEFFIELD 9.
Tel: 42411 (5 lines). Telex. 54-107

MEMBER OF THE HADFIELDS GROUP

LONDON SALES OFFICE: 25 BERKELEY SQUARE, W.1.
Tel: HYDe Park 0431

LONDON · PARIS · ROUEN · MONTREAL · OWEN SOUND

WELDING BRAZING AND SOLDERING OF WIGGIN HIGH-NICKEL ALLOYS

This handbook is essential

Send for your copy now

This new 86-page publication provides you with the most up-to-date data for guidance in joining Wiggin High-Nickel Alloys:—Oxy-acetylene, Metal-arc, Argon-arc, Resistance and Flash-butt welding. It also contains sections dealing with the welding of dissimilar metals and on the lining of vessels.

To Henry Wiggin & Company Ltd., Wiggin Street, Birmingham 16
Please send me without charge a copy of your new publication:—

'WELDING, BRAZING AND SOLDERING OF WIGGIN HIGH-NICKEL ALLOYS'

NAME _____

APPOINTMENT OR DEPT. _____

COMPANY AND ADDRESS _____

_____ BW/M33/12

HENRY WIGGIN & COMPANY LIMITED, WIGGIN STREET, BIRMINGHAM 16

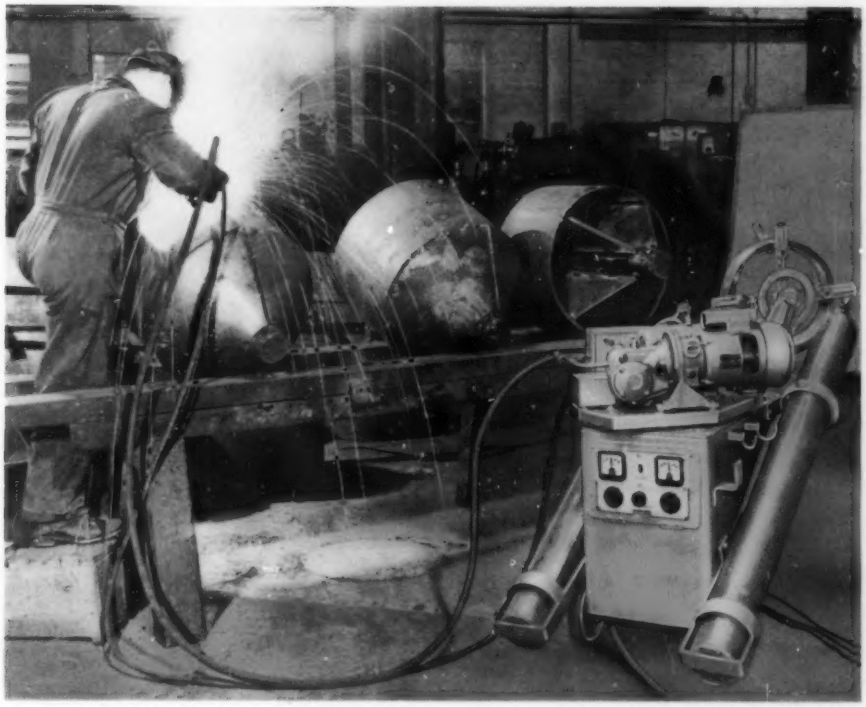
TGA M33

CO_2 WELDING

PHILIPS
LEAD AGAIN!

FASTEST MANUAL ALL-POSITION WELDING!

twice as fast as heavy-gauge manual electrodes



By courtesy of W. G. Watson (Welding) Ltd.

All-position welding—from overhead through vertical to downhand—twice as fast as heavy gauge manual electrodes—that's the achievement of this revolutionary new Philips CO_2 Welding Mobile Unit. It uses ordinary D.C. welding-power sources, either rectifier or motor-generator. The specially designed "easy-on-the-arm" welding gun gives perfect balance in the hand, and eliminates operator fatigue to a minimum. Ask for full details.

PHILIPS

OTHER LEADING FEATURES

- Wire-feed and welding current *automatically* stop and red warning lamp lights if gas fails.
- Wire feed infinitely variable between 6 and 54 F.p.m. Set by directly calibrated control.
- Wire controlled during welding by solenoid-operated pressure roll and adjustable straightening device.
- Three wire sizes: 0.9 mm. 1.2 mm. 1.6 mm. Only the gun contact-tip is changed.
- Coil holder carries 44 or 56 lb coils of wire, has adjustable automatic brake.
- Turntable mounting of wire-feed unit gives up to 20 ft of gun movement.
- Low-hydrogen welds of high radiographic quality are consistently made.

Sole distributors in the U.K.

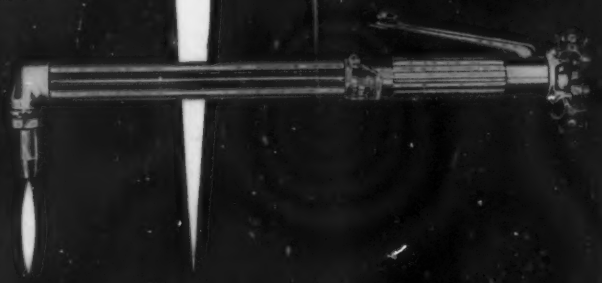
RESEARCH & CONTROL INSTRUMENTS LTD

207 KING'S CROSS ROAD, LONDON W.C.1 TELEPHONE: TERMINUS 2877

FROM BRITISH OXYGEN— FOR BRITISH INDUSTRY

cut ting

British Oxygen is constantly developing better tools for Industry. Whatever your cutting needs, we have a blowpipe or machine ready to do the job quickly and at low cost. Ask any of our 36 branch offices for experienced and expert advice.



The British Oxygen Company Ltd

LIGHT INDUSTRIAL DEPT · SPENCER HOUSE · 27 ST. JAMES'S PLACE · LONDON S.W.1

Outside back cover